About Lock-In Amplifiers

Application Note #3

Lock-in amplifiers are used to detect and measure very small AC signals—all the way down to a few nanovolts. Accurate measurements may be made even when the small signal is obscured by noise sources many thousands of times larger. Lock-in amplifiers use a technique known as phase-sensitive detection to single out the component of the signal at a specific reference frequency and phase. Noise signals, at frequencies other than the reference frequency, are rejected and do not affect the measurement.

Why Use a Lock-In?

Let's consider an example. Suppose the signal is a 10 nV sine wave at 10 kHz. Clearly some amplification is required to bring the signal above the noise. A good low-noise amplifier will have about 5 nV/√Hz of input noise. If the amplifier bandwidth is 100 kHz and the gain is 1000, we can expect our output to be 10 µV of signal (10 nV × 1000) and 1.6 mV of broadband noise (5 nV/√Hz × √100 kHz × 1000). We won't have much luck measuring the output signal unless we single out the frequency of interest.

If we follow the amplifier with a band pass filter with a Q=100 (a VERY good filter) centered at 10 kHz, any signal in a 100 Hz bandwidth will be detected (10 kHz/Q). The noise in the filter pass band will be 50 µV (5 nV/√Hz × √100 Hz × 1000), and the signal will still be 10 µV. The output noise is much greater than the signal, and an accurate measurement can not be made. Further gain will not help the signal-to-noise problem.

Now try following the amplifier with a phase-sensitive detector (PSD). The PSD can detect the signal at 10 kHz with a bandwidth as narrow as 0.01 Hz! In this case, the noise in the detection bandwidth will be 0.5 µV (5 nV/√Hz × √.01 Hz × 1000), while the signal is still 10 µV. The signal-to-noise ratio is now 20, and an accurate measurement of the signal is possible.

What is Phase-Sensitive Detection?

Lock-in measurements require a frequency reference. Typically, an experiment is excited at a fixed frequency (from an oscillator or function generator), and the lock-in detects the response from the experiment at the reference frequency. In the following diagram, the reference signal is a square wave at frequency ω_r. This might be the sync output from a function generator. If the sine output from the function generator is used to excite the experiment, the response might be the signal waveform shown below. The signal is $V_{sig}\sin(\omega_r t + \theta_{sig})$ where V_{sig} is the signal amplitude, ω_r is the signal frequency, and θ_{sig} is the signal's phase.

Lock-in amplifiers generate their own internal reference signal usually by a phase-locked-loop locked to the external reference. In the diagram, the external reference, the lock-in's reference, and the signal are all shown. The internal reference is $V_L\sin(\omega_L t + \theta_{ref})$.
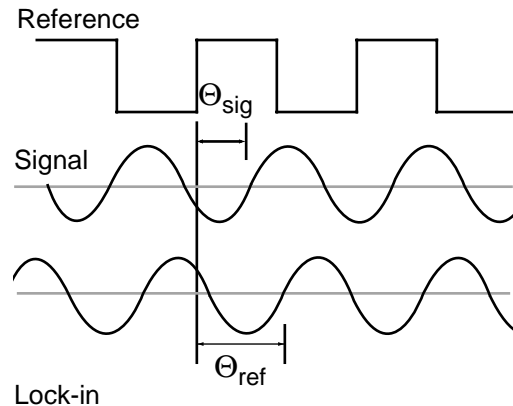
The lock-in amplifies the signal and then multiplies it by the lock-in reference using a phase-sensitive detector or multiplier. The output of the PSD is simply the product of two sine waves.

$$V_{psd} = V_{sig}V_L\sin(\omega_r t + \theta_{sig})\sin(\omega_L t + \theta_{ref})$$

$$= \tfrac{1}{2}V_{sig}V_L\cos([\omega_r - \omega_L]t + \theta_{sig} - \theta_{ref}) - \tfrac{1}{2}V_{sig}V_L\cos([\omega_r + \omega_L]t + \theta_{sig} + \theta_{ref})$$

The PSD output is two AC signals, one at the difference frequency $(\omega_r - \omega_L)$ and the other at the sum frequency $(\omega_r + \omega_L)$.

If the PSD output is passed through a low pass filter, the AC signals are removed. What will be left? In the general case, nothing. However, if ω_r equals ω_L, the difference frequency component will be a DC signal. In this case, the filtered PSD output will be:

$$V_{psd} = \tfrac{1}{2}V_{sig}V_L\cos(\theta_{sig} - \theta_{ref})$$

This is a very nice signal—it is a DC signal proportional to the signal amplitude.

It's important to consider the physical nature of this multiplication and filtering process in different types of lock-ins. In traditional analog lock-ins, the signal and reference are analog voltage signals. The signal and reference are multiplied in an analog multiplier, and the result is filtered with one or more stages of RC filters. In a digital lock-in, such as the SR830 or SR850, the signal and reference are represented by sequences of numbers. Multiplication and filtering are performed mathematically by a digital signal processing (DSP) chip. We'll discuss this in more detail later.

Narrow Band Detection

Let's return to our generic lock-in example. Suppose that instead of being a pure sine wave, the input is made up of signal plus noise. The PSD and low pass filter only detect

signals whose frequencies are very close to the lock-in reference frequency. Noise signals, at frequencies far from the reference, are attenuated at the PSD output by the low pass filter (neither $\omega_{noise} - \omega_{ref}$ nor $\omega_{noise} + \omega_{ref}$ are close to DC). Noise at frequencies very close to the reference frequency will result in very low frequency AC outputs from the PSD ($|\omega_{noise} - \omega_{ref}|$ is small). Their attenuation depends upon the low pass filter bandwidth and rolloff. A narrower bandwidth will remove noise sources very close to the reference frequency; a wider bandwidth allows these signals to pass. The low pass filter bandwidth determines the bandwidth of detection. Only the signal at the reference frequency will result in a true DC output and be unaffected by the low pass filter. This is the signal we want to measure.

Where Does the Lock-In Reference Come From?

We need to make the lock-in reference the same as the signal frequency, i.e. $\omega_r = \omega_L$. Not only do the frequencies have to be the same, the phase between the signals can not change with time. Otherwise, $\cos(\theta_{sig} - \theta_{ref})$ will change and V_{psd} will not be a DC signal. In other words, the lock-in reference needs to be phase-locked to the signal reference.

Lock-in amplifiers use a phase-locked loop (PLL) to generate the reference signal. An external reference signal (in this case, the reference square wave) is provided to the lock-in. The PLL in the lock-in amplifier locks the internal reference oscillator to this external reference, resulting in a reference sine wave at ω_r with a fixed phase shift of θ_{ref}. Since the PLL actively tracks the external reference, changes in the external reference frequency do not affect the measurement.

Internal Reference Sources

In the case just discussed, the reference is provided by the excitation source (the function generator). This is called an external reference source. In many situations the lock-in's internal oscillator may be used instead. The internal oscillator is just like a function generator (with variable sine output and a TTL sync) which is always phase-locked to the reference oscillator.

Magnitude and Phase

Remember that the PSD output is proportional to $V_{sig}\cos\theta$, where $\theta = (\theta_{sig} - \theta_{ref})$. θ is the phase difference between the signal and the lock-in reference oscillator. By adjusting θ_{ref} we can make θ equal to zero. In which case we can measure V_{sig} ($\cos\theta = 1$). Conversely, if θ is 90°, there will be no output at all. A lock-in with a single PSD is called a single-phase lock-in and its output is $V_{sig}\cos\theta$.

This phase dependency can be eliminated by adding a second PSD. If the second PSD multiplies the signal with the reference oscillator shifted by 90°, i.e. $V_L\sin(\omega_L t + \theta_{ref} + 90°)$, its low pass filtered output will be:

$$V_{psd2} = \tfrac{1}{2}V_{sig}V_L\sin(\theta_{sig} - \theta_{ref})$$

$$V_{psd2} \sim V_{sig}\sin\theta$$

Now we have two outputs: one proportional to $\cos\theta$ and the other proportional to $\sin\theta$. If we call the first output X and the second Y,

$$X = V_{sig}\cos\theta \qquad Y = V_{sig}\sin\theta$$

these two quantities represent the signal as a vector relative to the lock-in reference oscillator. X is called the 'in-phase' component and Y the 'quadrature' component. This is because when $\theta = 0$, X measures the signal while Y is zero.

By computing the magnitude (R) of the signal vector, the phase dependency is removed.

$$R = (X^2 + Y^2)^{1/2} = V_{sig}$$

R measures the signal amplitude and does not depend upon the phase between the signal and lock-in reference.

A dual-phase lock-in has two PSDs with reference oscillators 90° apart, and can measure X, Y and R directly. In addition, the phase (θ) between the signal and lock-in is defined as:

$$\theta = \tan^{-1}(Y/X)$$

Digital PSD vs. Analog PSD

We mentioned earlier that the implementation of a PSD is different for analog and digital lock-ins. A digital lock-in, such as the SR830, multiplies the signal with the reference sine waves digitally. The amplified signal is converted to digital form using a 16-bit A/D converter sampling at 256 kHz. The A/D converter is preceeded by a 102 kHz anti-aliasing filter to prevent higher frequency inputs from aliasing below 102 kHz.

This input data stream is multiplied, a point at a time, with the computed reference sine waves described previously. Every 4 μs the input signal is sampled, and the result is multiplied by both reference sine waves (90° apart).

The phase sensitive detectors (PSDs) in the digital lock-in act as linear multipliers; that is, they multiply the signal with a reference sine wave. Analog PSDs (both square wave and linear) have many problems associated with them. The main problems are harmonic rejection, output offsets, limited dynamic reserve, and gain error.

The digital PSD multiplies the digitized signal with a digitally computed reference sine wave. Because the reference sine waves are computed to 20 bits of accuracy, they have very low harmonic content. In fact, the harmonics are at the −120 dB level! This means that the signal is multiplied by a single reference sine wave (instead of a reference and its many harmonics), and only the signal at this single reference frequency is detected. The SR810, SR830 and SR850 digital lock-ins are completely insensitive to signals at harmonics of the reference. In contrast, a square wave multiplying lock-in will detect at all of the odd harmonics of the reference (a square wave contains many large odd harmonics).

Output offset is a problem because the signal of interest is a DC output from the PSD, and an output offset contributes to error and zero drift. The offset problems of analog PSDs are eliminated using the digital multiplier. There are no erroneous DC output offsets from the digital multiplication of the signal and reference. In fact, the actual multiplication is virtually error free.

The dynamic reserve of an analog PSD is limited to about 60 dB. When there is a large noise signal present, 1000 times (or 60 dB) greater than the full-scale signal, the analog PSD measures the signal with an error. The error is caused by non-linearity in the multiplication (the error at the output depends upon the amplitude of the input). This error can be quite large (10 % of full scale) and depends upon the noise amplitude, frequency and waveform. Since noise generally varies quite a bit in these parameters, the PSD error causes a lot of output uncertainty.

In the digital lock-in, dynamic reserve is limited by the quality of the A/D conversion. Once the input signal is digitized, no further errors are introduced. Certainly, the accuracy of the multiplication does not depend on the size of the numbers. The A/D converter used in the SR810, SR830 and SR850 is extremely linear, meaning that the presence of large noise signals does not impair its ability to correctly digitize a small signal. In fact, the dynamic reserve of these lock-ins can exceed 100 dB without any problems. We'll talk more about dynamic reserve a little later.

A linear, analog PSD multiplies the signal by an analog reference sine wave. Any amplitude variation in the reference amplitude shows up directly as a variation in the overall gain. Analog sine-wave generators are susceptible to amplitude drift: especially as a function of temperature. The digital reference sine wave has a precise amplitude and never changes. This avoids a major source of gain error common to analog lock-ins.

The overall performance of a lock-in amplifier is largely determined by the performance of its phase sensitive detectors. In virtually all respects, the digital PSD outperforms its analog counterparts.

What Does a Lock-In Measure?

So what exactly does the lock-in measure? Fourier's theorem basically states that any input signal can be represented as the sum of many sine waves of differing amplitudes, frequencies and phases. This is generally considered as representing the signal in the "frequency domain". Normal oscilloscopes display the signal in the "time domain". Except in the case of clean sine waves, the time domain representation does not convey very much information about the various frequencies which make up the signal.

A lock-in multiplies the signal by a pure sine wave at the reference frequency. All components of the input signal are multiplied by the reference simultaneously. Mathematically speaking, sine waves of differing frequencies are orthogonal, i.e. the average of the product of two sine waves is zero unless the frequencies are EXACTLY the same. The product of this multiplication yields a DC output signal proportional to the component of the signal whose frequency is exactly locked to the reference frequency. The low pass filter (which follows the multiplier) provides the averaging which removes the products of the reference with components at all other frequencies.

A lock-in amplifier, because it multiplies the signal with a pure sine wave, measures the single Fourier (sine) component of the signal at the reference frequency. Let's take a look at an example. Suppose the input signal is a simple square wave at frequency f. The square wave is actually composed of many sine waves at multiples of f with carefully related amplitudes and phases. A 2 Vpp square wave can be expressed as:

$$S(t) = 1.273\sin(\omega t) + 0.4244\sin(3\omega t) + 0.2546\sin(5\omega t) + ...$$

where $\omega = 2\pi f$. The lock-in, locked to f, will single out the first component. The measured signal will be $1.273\sin(\omega t)$, not the 2 Vpp that you'd measure on a scope.

In the general case, the input consists of signal plus noise. Noise is represented as varying signals at all frequencies. The ideal lock-in only responds to noise at the reference frequency. Noise at other frequencies is removed by the low pass filter following the multiplier. This "bandwidth narrowing" is the primary advantage that a lock-in amplifier provides. Only inputs with frequencies at the reference frequency result in an output.

RMS or Peak?

Lock-in amplifiers, as a general rule, display the input signal in volts rms. When a lock-in displays a magnitude of 1 V (rms), the component of the input signal (at the reference frequency) is a sine wave with an amplitude of 1 Vrms, or 2.8 Vpp.

Thus, in the previous example with a 2 Vpp square wave input, the lock-in would detect the first sine component, $1.273\sin(\omega t)$. The measured and displayed magnitude would be 0.90 Vrms (or $1.273/\sqrt{2}$).

Degrees or Radians?

In this discussion, frequencies have been referred to as f (Hz) and ω ($2\pi f$ radians/s). This is because people measure frequencies in cycles per second, and math works best in radians. For purposes of measurement, frequencies as measured in a lock-in amplifier are in Hz. The equations used to explain the actual calculations are sometimes written using ω to simplify the expressions.

Phase is always reported in degrees. Once again, this is more by custom than by choice. Equations written as $\sin(\omega t + \theta)$ are written as if θ is in radians, mostly for simplicity. Lock-in amplifiers always manipulate and measure phase in degrees.

Dynamic Reserve

The term "dynamic reserve" comes up frequently in discussions about lock-in amplifiers. It's time to discuss this

term in a little more detail. Assume the lock-in input consists of a full-scale signal at f_{ref} plus noise at some other frequency. The traditional definition of dynamic reserve is the ratio of the largest tolerable noise signal to the full-scale signal, expressed in dB. For example, if full scale is 1 µV, then a dynamic reserve of 60 dB means noise as large as 1 mV (60 dB greater than full scale) can be tolerated at the input without overload.

The problem with this definition is the word "tolerable". Clearly, the noise at the dynamic reserve limit should not cause an overload anywhere in the instrument—not in the input signal amplifier, PSD, low pass filter or DC amplifier. This is accomplished by adjusting the distribution of the gain. To achieve high reserve, the input signal gain is set very low so the noise is not likely to overload. This means that the signal at the PSD is also very small. The low pass filter removes the large noise components from the PSD output which allows the remaining DC component to be amplified (a lot) to reach 10 V full scale. There is no problem running the input amplifier at low gain. However, as we have discussed previously, analog lock-ins have a problem with high reserve because of the linearity of the PSD and the DC offsets of the PSD and DC amplifier. In an analog lock-in, large noise signals almost always disturb the measurement in some way.

The most common problem is a DC output error caused by the noise signal. This can appear as an offset or as a gain error. Since both effects are dependent upon the noise amplitude and frequency, they can not be offset to zero in all cases and will limit the measurement accuracy. Because the errors are DC in nature, increasing the time constant does not help. Most lock-ins define tolerable noise as levels which do not affect the output more than a few percent of full scale. This is more severe than simply not overloading.

Another effect of high dynamic reserve is to generate noise and drift at the output. This comes about because the DC output amplifier is running at very high gain, and low-frequency noise and offset drift at the PSD output or the DC amplifier input will be amplified and appear large at the output. The noise is more tolerable than the DC drift errors since increasing the time constant will attenuate the noise. The DC drift in an analog lock-in is usually on the order of 1000 ppm/°C when using 60 dB of dynamic reserve. This means that the zero point moves 1 % of full scale over 10 °C temperature change. This is generally considered the limit of tolerable.

Lastly, dynamic reserve depends on the noise frequency. Clearly noise at the reference frequency will make its way to the output without attenuation. So the dynamic reserve at f_{ref} is 0 dB. As the noise frequency moves away from the reference frequency, the dynamic reserve increases. Why? Because the low pass filter after the PSD attenuates the noise components. Remember, the PSD outputs are at a frequency of $|f_{noise} - f_{ref}|$. The rate at which the reserve increases depends upon the low pass filter time constant and rolloff. The reserve increases at the rate at which the filter rolls off. This is why 24 dB/oct filters are better than 6 or 12 dB/oct filters. When the noise frequency is far away, the reserve is limited by the

gain distribution and overload level of each gain element. This reserve level is the dynamic reserve referred to in the specifications.
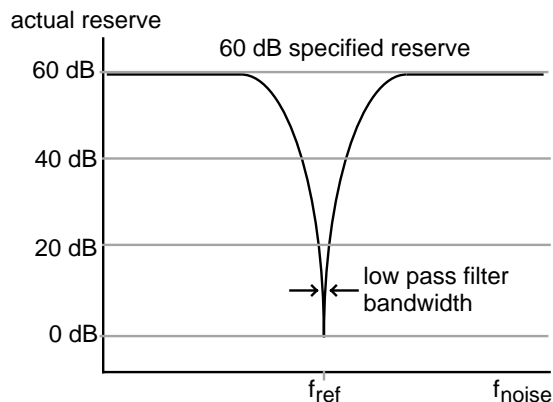
The above graph shows the actual reserve vs. the frequency of the noise. In some instruments, the signal input attenuates frequencies far outside the lock-in's operating range ($f_{noise} \gg 100$ kHz). In these cases, the reserve can be higher at these frequencies than within the operating range. While this creates a nice specification, removing noise at frequencies very far from the reference does not require a lock-in amplifier. Lock-ins are used when there is noise at frequencies near the signal. Thus, the dynamic reserve for noise within the operating range is more important.

Dynamic Reserve in Digital Lock-Ins

The SR810, SR830 and SR850, with their digital phase sensitive detectors, do not suffer from DC output errors caused by large noise signals. The dynamic reserve can be increased to above 100 dB without measurement error. Large noise signals do not cause output errors from the PSD. The large DC gain does not result in increased output drift.

In fact, the only drawback to using ultra-high dynamic reserves (>60 dB) is the increased output noise due to the noise of the A/D converter. This increase in output noise is only present when the dynamic reserve is increased above 60 dB *and* above the minimum reserve. (If the minimum reserve is 80 dB, then increasing to 90 dB may increase the noise. As we'll discuss next, the minimum reserve does not have increased output noise: no matter how large it is.)

To set a scale, the digital lock-in's output noise at 100 dB dynamic reserve is only measurable when the signal input is grounded. Let's do a simple experiment. If the lock-in reference is at 1 kHz, and a large signal is applied at 9.5 kHz, what will the lock-in output be? If the signal is increased to the dynamic reserve limit (100 dB greater than full scale), the output will reflect the noise of the signal at 1 kHz. The spectrum of any pure sine generator always has a noise floor, i.e. there is some noise at all frequencies. So even though the

applied signal is at 9.5 kHz, there will be noise at all other frequencies, including the 1 kHz lock-in reference. This noise will be detected by the lock-in and appear as noise at the output. This output noise will typically be greater than the lock-in's own output noise. In fact, virtually all signal sources will have a noise floor which will dominate the lock-in output noise. Of course, noise signals are generally much noisier than pure sine generators and will have much higher broadband noise floors.

If the noise does not reach the reserve limit, the digital lock-in's own output noise may become detectable at ultra-high reserves. In this case, simply lower the dynamic reserve and the DC gain will decrease, and the output noise will decrease also. In general, do not run with more reserve than necessary. Certainly don't use ultra-high reserve when there is virtually no noise at all.

The frequency dependence of dynamic reserve is inherent in the lock-in detection technique. The SR810, SR830 and SR850, by providing more low-pass filter stages, can increase the dynamic reserve close to the reference frequency. The specified reserve applies to noise signals within the operating range of the lock-in, i.e. frequencies below 100 kHz. The reserve at higher frequencies is actually greater but is generally not that useful.

Minimum Dynamic Reserve

The SR810, SR830 and SR850 always have a minimum amount of dynamic reserve. This minimum reserve changes with the sensitivity (gain) of the instrument. At high gains (full-scale sensitivity of 50 µV and below), the minimum dynamic reserve increases from 37 dB at the same rate as the sensitivity increases. For example, the minimum reserve at 5 µV sensitivity is 57 dB. In many analog lock-ins, the reserve can be lower. Why can't the digital lock-ins run with lower reserve at this sensitivity?

The answer to this question is: "Why would you want lower reserve?" In an analog lock-in, lower reserve means less output error and drift. In the SR800 series lock-ins, more reserve does not increase the output error or drift. But, more reserve can increase the output noise. However, if the analog signal gain before the A/D converter is high enough, the 5 nV/√Hz noise of the signal input will be amplified to a level greater than the input noise of the A/D converter. At this point, the detected noise will reflect the actual noise at the signal input and not the A/D converter's noise. Increasing the analog gain (decreasing the reserve) will not decrease the output noise. Thus, there is no reason to decrease the reserve. At a sensitivity of 5 µV, the analog gain is sufficiently high so that A/D converter noise is not a problem. Sensitivities below 5 µV do not require any more gain since the signal-to-noise ratio will not be improved (the front-end noise dominates). The SR800 series lock-ins do not increase their gain below the 5 µV sensitivity. Instead, the minimum reserve increases. Of course, the input gain can be decreased and the reserve increased; in which case, the A/D converter noise might be detected in the absence of any signal input.

Dynamic Reserve in Analog Lock-Ins

Because of the limitations of their PSDs, analog lock-in amplifiers must use different techniques to improve their dynamic reserve. The most common of these is the use of analog prefilters. The SR510 and SR530 have tunable, band-pass filters at their inputs. The filters are designed to automatically track the reference frequency. If an interfering signal is attenuated by a filter before it reaches the lock-in input, the dynamic reserve of the lock-in will be increased by that amount. For the SR510 and SR530, a dynamic reserve increase of up to 20 dB can be realized using the input band pass filter. Of course, such filters add their own noise and contribute to phase error: so they should only be used if necessary.

A lock-in can measure signals as small as a few nanovolts. A low-noise signal amplifier is required to boost the signal to a level where the A/D converter can digitize the signal without degrading the signal-to-noise. The analog gain in the SR850 ranges from roughly 7 to 1000. As discussed previously, higher gains do not improve signal-to-noise and are not necessary.

The overall gain (AC and DC) is determined by the sensitivity. The distribution of the gain (AC versus DC) is set by the dynamic reserve.

Input Noise

The input noise of the SR810, SR830 or SR850 signal amplifier is about 5 nVrms/√Hz. The SR530 and SR510 lock-ins have 7 nVrms/√Hz of input noise. What does this noise figure mean? Let's set up an experiment. If an amplifier has 5 nVrms/√Hz of input noise and a gain of 1000, then the output will have 5 µVrms/√Hz of noise. Suppose the amplifier output is low-pass filtered with a single RC filter (6 dB/oct rolloff) with a time constant of 100 ms. What will be the noise at the filter output?

Amplifier input noise and Johnson noise of resistors are Gaussian in nature. That is, the amount of noise is proportional to the square root of the bandwidth in which the noise is measured. A single stage RC filter has an equivalent noise bandwidth (ENBW) of $1/4T$, where T is the time constant ($R \times C$). This means that Gaussian noise at the filter input is filtered with an effective bandwidth equal to the ENBW. In this example, the filter sees 5 µVrms/√Hz of noise at its input. It has an ENBW of $1/(4 \times 100 \text{ ms})$ or 2.5 Hz. The voltage noise at the filter output will be 5 µVrms/√Hz $\times$ √2.5 Hz, or 7.9 µVrms. For Gaussian noise, the peak-to-peak noise is about 5 times the rms noise. Thus, the output will have about 40 µVpp of noise.

Input noise for a lock-in works the same way. For sensitivities below about 5 µV full scale, the input noise will determine the output noise (at minimum reserve). The amount of noise at the output is determined by the ENBW of the low pass filter. The ENBW depends upon the time constant and filter rolloff. For example, suppose the lock-in is set to 5 µV full scale, with a 100 ms time constant, and 6 dB/oct of filter rolloff. The lock-in

will measure the input noise with an ENBW of 2.5 Hz. This translates to 7.9 nVrms at the input. At the output, this represents about 0.16 % of full scale (7.9 nV/5 µV). The peak-to-peak noise will be about 0.8 % of full scale.

All of this assumes that the signal input is being driven from a low impedance source. Remember resistors have Johnson noise equal to $0.13 \times \sqrt{R}$ nVrms/$\sqrt{Hz}$. Even a 50 Ω resistor has almost 1 nVrms/$\sqrt{Hz}$ of noise! A signal source impedance of 2 kΩ will have a Johnson noise greater than the lock-in's input noise. To determine the overall noise of multiple noise sources, take the square root of the sum of the squares of the individual noise figures. For example, if a 2 kΩ source impedance is used, the Johnson noise will be 5.8 nVrms/$\sqrt{Hz}$. The overall noise at the lock-in's input will be $[5^2 + 5.8^2]^{\frac{1}{2}}$, or 7.7 nVrms/$\sqrt{Hz}$.

Noise Sources

What is the origin of the noise we've been discussing? There are two types of noise we have to worry about in laboratory situations: intrinsic noise and external noise. Intrinsic noise sources, like Johnson noise and shot noise, are inherent to all physical processes. Though we cannot get rid of intrinsic noise sources, by being aware of their nature we can minimize their effects. External noise sources are found in the environment—such as power line noise and broadcast stations. The effect of these noises sources can be minimized by careful attention to grounding, shielding, and other aspects of experimental design. We will first discuss some of the sources of intrinsic noise.

Johnson Noise

Every resistor generates a noise voltage across its terminals due to thermal fluctuations in the electron density within the resistor itself. These fluctuations give rise to an open-circuit noise voltage:

$$V_{noise}(rms) = \left(4k\,TR\,\Delta f\right)^{1/2}$$

where k=Boltzmann's constant (1.38×10^{-23} J/°K), T is the temperature in Kelvin (typically 300 °K), R is the resistance in ohms, and Δf is the bandwidth of the measurement in Hz.

Since the input signal amplifier in a lock-in typically has a bandwidth of approximately 300 kHz, the effective noise at the amplifier input is $V_{noise}=70\sqrt{R}$ nVrms, or $350\sqrt{R}$ nVpp. This noise is broadband. So if the source impedance is large, it can determine the amount of dynamic reserve required.

The amount of noise measured by the lock-in is determined by the measurement bandwidth. Remember, the lock-in does not narrow its detection bandwidth until after the phase sensitive detectors. In a lock-in, the equivalent noise bandwidth (ENBW) of the low pass filter (time constant) sets the detection bandwidth. In this case, the measured noise of a resistor at the lock-in input, typically the source impedance of the signal, is simply:

$$V_{noise}(rms) = 0.13\sqrt{R}\,\sqrt{ENBW}\ nV$$

Shot Noise

Electric current has noise due to the finite nature of the charge carriers. There is always some non-uniformity in the electron flow which generates noise in the current. This noise is called "shot noise". This can appear as voltage noise when current is passed through a resistor, or as noise in a current measurement. The shot noise, or current noise, is given by:

$$I_{noise}(rms) = \left(2qI\Delta f\right)^{1/2}$$

where q is the electron charge (1.6×10^{-19} Coulomb), I is the rms AC current or DC current depending upon the circuit, and Δf is the bandwidth.

When the current input of a lock-in is used to measure an AC signal current, the bandwidth is typically so small that shot noise is not important.

1/f Noise

Every 10 Ω resistor, no matter what it is made of, has the same Johnson noise. However, there is excess noise in addition to Johnson noise which arises from fluctuations in resistance due to the current flowing through the resistor. For carbon composition resistors, this is typically 0.1 µV to 3 µV of rms noise per volt applied across the resistor. Metal film and wire-wound resistors have about 10 times less noise. This noise has a 1/f spectrum and makes measurements at low frequencies more difficult. Other sources of 1/f noise include noise found in vacuum tubes and semiconductors.

Total Noise

All of these noise sources are incoherent. The total random noise is the square root of the sum of the squares of all the incoherent noise sources.

External Noise Sources

In addition to the intrinsic noise sources discussed previously, there are a variety of external noise sources within the laboratory. Most of these noise sources are asynchronous, i.e. they are not related to the reference, and do not occur at the reference frequency or its harmonics. Examples include lighting fixtures, motors, cooling units, radios, computer screens, etc. These noise sources affect the measurement by increasing the required dynamic reserve or lengthening the time constant.

Some noise sources, however, are related to the reference, and if picked up in the signal, will add or subtract from the actual signal and cause errors in the measurement. Typical sources of synchronous noise are ground loops between the experiment, detector and lock-in; and electronic pick up from the reference oscillator or experimental apparatus.

Many of these noise sources can be minimized with good laboratory practice and experiment design. There are several ways in which noise sources are coupled into the signal path.

Capacitive Coupling

An AC voltage from a nearby piece of apparatus can couple to a detector via stray capacitance. Although C_{stray} may be very small, the coupled noise may still be larger than a weak experimental signal. This is especially damaging if the coupled noise is synchronous (at the reference frequency).
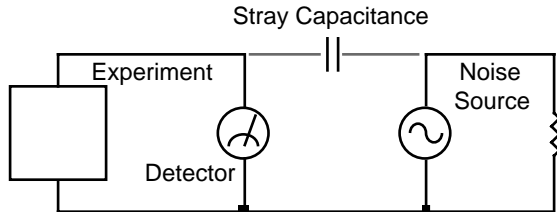
We can estimate the noise current caused by a stray capacitance by:

$$i = C_{stray} \frac{dV}{dt} = \omega C_{stray} V_{noise}$$

where ω is 2π times the noise frequency, V_{noise} is the noise amplitude, and C_{stray} is the stray capacitance.

For example, if the noise source is a power circuit, then f = 60 Hz and V_{noise} = 120 V. C_{stray} can be estimated using a parallel plate equivalent capacitor. If the capacitance is roughly an area of 1 cm^2 separated by 10 cm, then C_{stray} is 0.009 pF. The resulting noise current will be 400 pA (at 60 Hz). This small noise current can be thousands of times larger than the signal current. If the noise source is at a higher frequency, the coupled noise will be even greater.

If the noise source is at the reference frequency, the problem is much worse. The lock-in rejects noise at other frequencies, but pick-up at the reference frequency appears as signal!

Cures for capacitive noise coupling include:

1) Removing or turning off the noise source.

2) Keeping the noise source far from the experiment (reducing C_{stray}). Do not bring the signal cables close to the noise source.

3) Designing the experiment to measure voltages with low impedance (noise current generates very little voltage).

4) Installing capacitive shielding by placing both the experiment and detector in a metal box.

Inductive Coupling

An AC current in a nearby piece of apparatus can couple to the experiment via a magnetic field. A changing current in a nearby circuit gives rise to a changing magnetic field which induces an emf ($d\emptyset_B/dt$) in the loop connecting the detector to the experiment. This is like a transformer with the experiment-detector loop as the secondary winding.
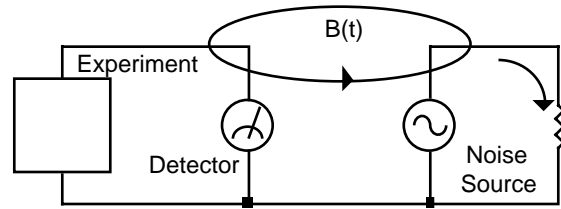
Cures for inductively coupled noise include:

1) Removing or turning off the interfering noise source.

2) Reduce the area of the pick-up loop by using twisted pairs or coaxial cables, or even twisting the two coaxial cables used in differential connections.

3) Using magnetic shielding to prevent the magnetic field from crossing the area of the experiment.

4) Measuring currents (not voltages) from high-impedance detectors.

Resistive Coupling or Ground Loops

Currents flowing through the ground connections can give rise to noise voltages. This is especially a problem with reference frequency ground currents.
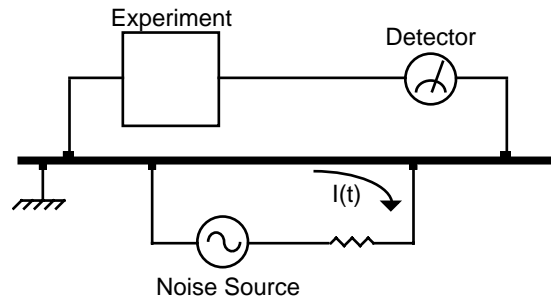
In this illustration, the detector is measuring the signal relative to a ground far from the rest of the experiment. The experiment senses the detector signal as well as the voltage from the noise source's ground return current, which passes through the finite resistance of the ground between the experiment and the detector. The detector and the experiment are grounded at different places which, in this case, are at different potentials.

Cures for ground loop problems include:

1) Grounding everything to the same physical point.

2) Using a heavy ground bus to reduce the resistance of ground connections.

3) Removing sources of large ground currents from the ground bus used for small signals.

Microphonics

Not all sources of noise are electrical in origin. Mechanical noise can be translated into electrical noise by microphonic effects. Physical changes in the experiment or cables (due to vibrations for example) can result in electrical noise over the entire frequency range of the lock-in.

For example, consider a coaxial cable connecting a detector to a lock-in. The capacitance of the cable is a function of its geometry. Mechanical vibrations in the cable translate into a capacitance that varies in time—typically at the vibration frequency. Since the cable is governed by Q=CV, taking the derivative yields:

$$C\frac{dV}{dt} + V\frac{dC}{dt} = \frac{dQ}{dt} = i$$

Mechanical vibrations in the cable which cause a dC/dt will give rise to a current in the cable. This current affects the detector and the measured signal.

Some ways to minimize microphonic signals are:

1) Eliminate mechanical vibrations near the experiment.

2) Tie down cables carrying sensitive signals so they do not move.

3) Use a low noise cable that is designed to reduce microphonic effects.

Thermocouple Effects

The emf created by junctions between dissimilar metals can give rise to many microvolts of slowly varying potentials. This source of noise is typically at very low frequency since the temperature of the detector and experiment generally changes slowly. This effect is large on the scale of many detector outputs, and can be a problem for low frequency measurements: especially in the mHz range. Some ways to minimize thermocouple effects are:

1) Hold the temperature of the experiment or detector constant.

2) Use a compensation junction, i.e. a second junction in reverse polarity which generates an emf to cancel the thermal potential of the first junction. This second junction should be held at the same temperature as the first junction.

Input Connections

In order to achieve the best accuracy for a given measurement,

care must be taken to minimize the various noise sources which can be found in the laboratory. With intrinsic noise (Johnson noise, 1/f noise or input noise), the experiment or detector must be designed with these noise sources in mind. These noise sources are present regardless of the input connections. The effect of noise sources in the laboratory (such as motors, signal generators, etc.), and the problem of differential grounds between the detector and the lock-in, can be minimized by careful input connections.

There are two basic methods for connecting a voltage signal to the lock-in amplifier; the single-ended connection is more convenient while the differential connection eliminates spurious pick-up more effectively.

Single-Ended Voltage Connection (A)

In the first method, the lock-in uses the A input in a single-ended mode. The lock-in detects the signal as the voltage between the center and outer conductors of the A input only. The lock-in does not force the shield of the A cable to ground. Rather, it is internally connected to the lock-in's ground via a resistor. The value of this resistor is typically between 10 Ω and 1 kΩ. The SR810, SR830 and SR850 let you choose the value of this resistor. This avoids ground loop problems between the experiment and the lock-in due to differing ground potentials. The lock-in lets the shield 'quasi-float' in order to sense the experiment ground. However, noise pickup on the shield will appear as noise to the lock-in. This is bad since the lock-in cannot reject this noise. Common mode noise, which appears on both the center and shield, is rejected by the 100 dB CMRR of the lock-in input, but noise on only the shield is not rejected at all.

Grounds may be at different potentials
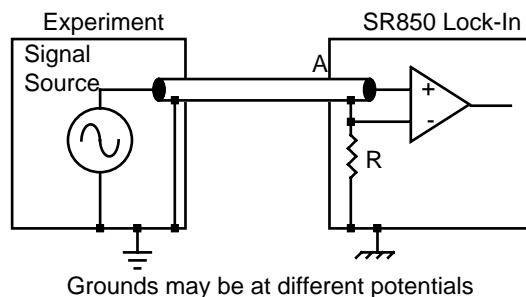
Differential Voltage Connection (A−B)

The second method of connection is the differential mode. The lock-in measures the voltage difference between the center conductors of the A and B inputs. Both of the signal connections are shielded from spurious pick-up. Noise pickup on the shields does not translate into signal noise since the shields are ignored.

When using two cables, it is important that both cables travel the same path between the experiment and the lock-in. Specifically, there should not be a large loop area enclosed by

the two cables. Large loop areas are susceptible to magnetic pickup.

Grounds may be at different potentials
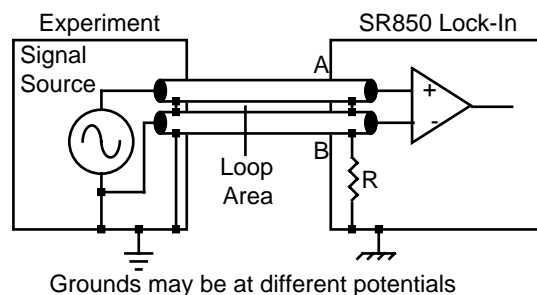
Common Mode Signals

Common mode signals are those signals which appear equally on both center and shield (A) or both A and B (A−B). With either connection scheme, it is important to minimize both the common mode noise and the common mode signal. Notice that the signal source is held near ground potential in both illustrations above. If the signal source floats at a nonzero potential, the signal which appears on both the A and B inputs will not be perfectly cancelled. The common mode rejection ratio (CMRR) specifies the degree of cancellation. For low frequencies, the CMRR of 100 dB indicates that the common mode signal is canceled to 1 part in 10^5. Even with a CMRR of 100 dB, a 100 mV common mode signal behaves like a 1 μV differential signal! This is especially bad if the common mode signal is at the reference frequency (this happens a lot due to ground loops). The CMRR decreases by about 6 dB/oct (20 dB/decade) starting at around 1 kHz.

The Lock-In as a Noise Measurement Device

Lock-in amplifiers can be used to measure noise. Noise measurements are generally used to characterize components and detectors. Remember that the lock-in detects signals close to the reference frequency. How close? Input signals within the detection bandwidth set by the low-pass-filter time constant and rolloff appear at the output at a frequency $f = f_{sig} - f_{ref}$. Input noise near f_{ref} appears as noise at the output with a bandwidth of DC to the detection bandwidth.

The noise is simply the standard deviation (root of the mean of the squared deviations) of the measured X, Y or R. You can measure this noise exactly by recording a sequence of output values and then calculating the standard deviation directly. The noise, in volts/√Hz, is simply the standard deviation divided by the square root of the equivalent noise bandwidth of the time constant.

For Gaussian noise, the equivalent noise bandwidth (ENBW) of a low pass filter is the bandwidth of the perfect rectangular filter which passes the same amount of noise as the real filter.

Noise Estimation

The above technique, while mathematically sound, can not provide a real-time output or an analog output proportional to the measured noise. Lock-ins (such as the SR510, SR530, SR810, SR830 and SR850) do provide these features, however. The quantity X_{noise} is computed from the measured values of X using the following algorithm. The moving average of X is computed. This is the mean value of X over some past history. The present mean value of X is subtracted from the present value of X to find the deviation of X from the mean. Finally, the moving average of the absolute value of the deviations is calculated. This calculation is called the mean average deviation, or MAD. This is not the same as an rms calculation. However, if the noise is Gaussian in nature, the rms noise and the MAD noise are related by a constant factor.

SRS lock-in amplifiers use the MAD method to estimate the rms noise quantities Xn, Yn and Rn. The advantage of this technique is its numerical simplicity and speed. For most applications, noise estimation and standard deviation calculations yield the same answer. Which method you use depends upon the requirements of the experiment.

MODEL SR530
LOCK-IN AMPLIFIER

SRS **Stanford Research Systems**

Table of Contents

Safety and Preparation for Use

CAUTION: This instrument may be damaged if operated with the LINE VOLTAGE SELECTOR set for the wrong applied ac input-source voltage or if the wrong fuse is installed.

LINE VOLTAGE SELECTION

The SR530 operates from a 100V, 120V, 220V, or 240V nominal ac power source having a line frequency of 50 or 60 Hz. Before connecting the power cord to a power source, verify that the LINE VOLTAGE SELECTOR card, located in the rear panel fuse holder, is set so that the correct ac input voltage value is visible.

Conversion to other ac input voltages requires a change in the fuse holder voltage card position and fuse value. Disconnect the power cord, open the fuse holder cover door and rotate the fuse-pull lever to remove the fuse. Remove the small printed circuit board and select the operating voltage by orienting the printed circuit board to position the desired voltage to be visible when pushed firmly into its slot. Rotate the fuse-pull lever back into its normal position and insert the <u>correct</u> fuse into the fuse holder.

LINE FUSE

Verify that the correct line fuse is installed before connecting the line cord. For 100V and 120V, use a ½ Amp fuse and for 220V and 240V, use a 1/4 Amp fuse.

LINE CORD

This instrument has a detachable, three-wire power cord with a three-contact plug for connection to both the power source and protective ground. The protective ground contact connects to the accessible metal parts of the instrument. To prevent electrical shock, always use a power source outlet that has a properly grounded protective-ground contact.

FURNISHED ACCESSORIES

- Power Cord
- Operating Manual

ENVIRONMENTAL CONDITIONS

OPERATING
Temperature: +10° C to +40° C
(Specifications apply over +18° C to +28° C)
Relative Humidity: < 90% Non-condensing

NON-OPERATING
Temperature: -25° C to 65° C
Humidity: < 95% Non-condensig
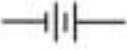
OPERATE WITH COVERS IN PLACE

To avoid personal injury, do not remove the product covers or panels. Do not operate the product without all covers and panels in place.

WARNING REGARDING USE WITH PHOTOMULTIPLIERS

It is relatively easy to damage the signal inputs if a photomultiplier is used improperly with the lock-in amplifier. When left completely unterminated, a PMT will charge a cable to a few hundred volts in a very short time. If this cable is connected to the lockin, the stored charge may damage the front-end transistors. To avoid this problem, provide a leakage path of about 100 KΩ to ground inside the base of the PMT to prevent charge accumulation.

Symbols you may find on SRS products.

Symbol	Description
$\sim$	Alternating current
⚡	Caution - risk of electric shock
⏚	Frame or chassis terminal
⚠	Caution - refer to accompanying documents
⏚	Earth (ground) terminal
—⊣⊢—	Battery
⌒⌒	Fuse
|	On (supply)
○	Off (supply)

SR530 Specification Summary

General

Power	100, 120, 220, 240 VAC (50/60 Hz); 35 Watts Max
Mechanical	17" x 17" x 5.25" (Rack Mount Included) 16 lbs.
Warranty	Two years parts and labor.

Signal Channel

Inputs	Voltage:	Single-ended or True Differential
	Current:	10^6 Volts/Amp
Impedance	Voltage:	100 MΩ + 25 pF, ac coupled
	Current:	1 kΩ to virtual ground
Full Scale Sensitivity	Voltage:	100 nV (10 nV on expand) to 500 mV
	Current:	100 fA to 0.5 μA
Maximum Inputs	Voltage:	100 VDC, 10 VAC damage threshold
		2 VAC peak-to-peak saturation
	Current:	10 mA damage threshold
		1 μA ac peak-to-peak saturation
Noise	Voltage:	7 nV/$\sqrt{}$Hz at 1 kHz
	Current:	0.13 pA/$\sqrt{}$ Hz at 1 kHz
Common Mode	Range:	1 Volt peak; Rejection: 100 dB dc to 1KHz
		Above 1KHz the CMRR degrades by 6 dB/Octave
Gain Accuracy	1% (2 Hz to 100KHz)	
Gain Stability	200 ppm/°C	
Signal Filters	60 Hz notch, -50 dB (Q=10, adjustable from 45 to 65 Hz)	
	120 Hz notch, -50 dB (Q=10, adjustable from 100 to 130 Hz))	
	Tracking bandpass set to within 1% of ref freq (Q=5)	
Dynamic Reserve	20 dB LOW (1 μV to 500 mV sensitivity)	
	40 dB NORM (100 nV to 50 mV sensitivity)	
	60 dB HIGH (100 nV to 5 mV sensitivity)	
	Bandpass filter adds 20 dB to dynamic reserve	
	Line Notch filters increase dynamic reserve to 100 dB	

Reference Channel

Frequency	0.5 Hz to 100 kHz	
Input Impedance	1 MΩ, ac coupled	
Trigger	SINE:	100 mV minimum, 1Vrms nominal
	PULSE:	±1 Volt, 1 μsec minimum width
Mode	Fundamental (f) or 2nd Harmonic (2f)	

Acquisition Time	25 Sec at 1 Hz
	6 Sec at 10 Hz
	2 Sec at 10 kHz
Slew Rate	1 decade per 10 S at 1 kHz
Phase Control	90° shifts
	Fine shifts in 0.025° steps
Phase Noise	0.01° rms at 1 kHz, 100 msec, 12 dB TC
Phase Drift	0.1°/°C
Phase Error	Less than 1° above 10Hz
Orthogonality	90° ± 1°

Demodulator

Stability	5 ppm/°C on LOW dynamic reserve
	50 ppm/°C on NORM dynamic reserve
	500 ppm/°C on HIGH dynamic reserve
Time Constants	Pre: 1msec to 100 sec (6 dB/Octave)
	Post: 1sec, 0.1 sec, none (6 dB/Octave) or none
Offset	Up to 1X full scale (10X on expand)
	Both channels may be offset
Harmonic Rej	-55 dB (bandpass filter in)

Outputs & Interfaces

Channel 1 Outputs	X (RcosØ), X Offset, R (magnitude), R Offset, X Noise, X5 (external D/A)
Channel 2 Outputs	Y (RsinØ), Y Offset, Ø (phase shift of signal), Y Noise, X6 (external D/A)
Output Meters	2% Precision mirrored analog meter
Output LCD's	Four digit auto-ranging LCD display shows same values as the analog meters
Output BNC's	±10 V output corresponds to full scale input, <1Ω output impedance
X Output	X (RcosØ), ±10 V full scale, < 1Ω output impedance
Y Output	Y (RsinØ), ±10 V full scale, < 1Ω output impedance
Reference LCD	Four digit LCD display for reference phase shift or frequency
RS232	Interface controls all functions. Baud rates from 300 to 19.2 K
GPIB	Interface controls all functions. (IEEE-488 Std)
A/D	4 BNC inputs with 13 bit resolution (±10.24 V)
D/A	2 BNC outputs with 13 bit resolution (±10.24 V)
Ratio	Ratio output equals 10X Channel 1 output divided by the Denominator input.
Internal Oscillator	Range: 1 Hz to 100 kHz, 1% accuracy
	Stability: 150 ppm/°C
	Distortion: 2% THD
	Amplitude: 1% accuracy, 500 ppm/°C stability

Front Panel Summary

Signal Inputs   Single Ended (A), True Differential (A-B), or Current (I)

Signal Filters   Bandpass: Q-of-5 Auto-tracking filter (In or Out)
Line Notch: Q-of-10 Notch Filter at line frequency (In or Out)
2XLine Notch: Q-of-10 Notch Filter at twice line frequency (In or Out)

Sensitivity   Full scale sensitivity from 100 nV to 500 mV RMS for voltage inputs
or from 100 fA to 500 nA RMS for current inputs.

Dynamic Reserve

Select	Dynamic Reserve	Stability	Sensitivity Ranges
LOW	20 dB	5 ppm	1 μV to 500 mV
NORM	40 dB	50 ppm	100 nV to 50 mV
HIGH	60 dB	500 ppm	100 nV to 5 mV

Status Indicators   OVLD Signal Overload
UNLK PLL is not locked to the reference input
ERR   Illegal or Unrecognized command
ACT   RS232 or GPIB interface Activity
REM   Remote mode: front panel has been locked-out

Display Select

Channel 1	Channel 2
X (RcosØ)	Y (RsinØ)
X Offset	Y Offset
R (Magnitude)	Ø (Phase)
R Offset	Ø (no offset)
X Noise	Y Noise
X5 (D/A)	X6 (D/A)

Analog Meters   Displays Channel 1 and 2 Outputs as a fraction of full scale

Output LCD's   Displays the Channel 1 and 2 Outputs in absolute units

Output BNC's   Channel 1 and 2 Outputs follow Analog Meters, ± 10 V for ± full scale

Expand   Multiplies the Channel 1 or 2 Analog Meter and Output voltage by a factor X1 or X10.

REL   Set the Channel 1 or 2 Offset to null the output: subsequent readings are relative
readings. REL with phase display performs auto-phasing. REL with X5, X6 display
zeroes the D/A outputs.

Offset   Enables or Disables Offset, and allows any offset (up to full scale) to be entered. X, Y,
and R may be offset and X5, X6 may be adjusted. Phase is offset using the reference
phase shift.

X BNC   X (RcosØ) output, ± 10V full scale

Y BNC   Y (RsinØ) output, ± 10V full scale

Reference Input   1 MΩ Input, 0.5 Hz to 100 KHz, 100 mV minimum

Reference Trigger Trigger on rising edge, zero crossing, or falling edge

f/2f Mode   PLL can lock to either X1 or X2 of the reference input frequency

Phase Controls	Adjust phase in smoothly accelerating 0.025° steps, or by 90° steps. Press both 90° buttons to zero the phase.
Reference LCD	Display reference phase setting or reference frequency
Time Constants	Pre-filter has time constants from 1 mS to 100 S (6 dB/Octave) Post-filter has time constants of 0, 0.1 or 1.0 S (6 dB/Octave)
ENBW	Equivalent Noise Bandwidth. Specifies the bandwidth when making Noise measurements. (1Hz or 10 Hz ENBW)
Power Switch	Instrument settings from the last use are recalled on power-up

Abridged Command List

AX	Auto offset X
AY	Auto offset Y
AR	Auto offset R
AP	Auto phase
B	Return Bandpass Filter Status
B0	Take out the Bandpass Filter
B1	Put in the Bandpass Filter
C	Return the Reference LCD Status
C0	Display the Reference Frequency
C1	Display the Reference Phase Shift
D	Return Dynamic Reserve Setting
D0	Set DR to LOW range
D1	Set DR to NORM range
D2	Set DR to HIGH range
En	Return Channel n (1 or 2) Expand Status
En,0	Turn Channel n Expand off
En,1	Turn Channel n Expand on
F	Return the Reference Frequency
G	Return the Sensitivity Setting
G1	Select 10 nV Full-Scale
...	(G1-G3 with SRS preamp only)
G24	Select 500 mV Full-Scale
H	Return Preamp Status (1=installed)
I	Return the Remote/Local Status
I0	Select Local: Front panel active
I1	Select Remote: Front panel inactive
I2	Select Remote with full lock-out
J	Set RS232 End-of-Record to \<cr\>
Jn,m,o,p	Set End-of-record to n,m,o,p
K1	Simulates Key-press of button #1
...	(see un-abridged command list)
K32	Simulates Key-press of button #32
L1	Return Status of Line Notch Filter
L1,0	Remove Line Notch Filter
L1,1	Insert Line Notch Filter
L2	Return Status of 2XLine Filter
L2,0	Remove 2XLine Notch Filter
L2,1	Insert 2XLine Notch Filter
M	Return the f/2f Status
M0	Set reference mode to f
M1	Set reference mode to 2f
N	Return the ENBW setting
N0	Select 1 Hz ENBW
N1	Select 10 Hz ENBW

OX	Return X Offset Status
OX 0	Turn off X Offset
OX 1,v	Turn on X Offset, v = offset
OY	Return Y Offset Status
OY 0	Turn off Y Offset
OY 1,v	Turn on Y Offset, v = offset
OR	Return R Offset Status
OR 0	Turn off R Offset
OR 1,v	Turn on R Offset, v = offset
P	Return the Phase Setting
Pv	Set the Phase to v. Abs(v) <999 deg
Q1	Return the Channel 1 output
Q2	Return the Channel 2 output
QX	Return the X Output
QY	Return the Y Output
R	Return the trigger mode
R0	Set the trigger for rising edge
R1	Set the trigger for + zero crossing
R2	Set the trigger for falling edge
S	Return the display status
S0	Display X and Y
S1	Display X and Y Offsets
S2	Display R and Ø
S3	Display R Offset and Ø
S4	Display X and Y noise
S5	Display X5 and X6 (ext D/A)
T1	Return pre-filter setting
T1,1	Set the pre-filter TC to 1 mS
...	
T1,11	Set the pre-filter TC to 100 S
T2	Return the post-filter setting
T2,0	Remove post filter
T2,1	Set the post filter TC to 0.1 S
T2,2	Set the post filter TC to 1.0 S
V	Return the value of the SRQ mask
Vn	Set the SRQ Mask to the value n (See the Status Byte definition)
W	Return the RS232 wait interval
Wn	Set RS232 wait interval to nX4mS
Xn	Return the voltage at the rear panel analog port n. (n from 1 to 6)
X5,v	Set analog port 5 to voltage v
X6,v	Set analog port 6 to voltage v
Y	Return the Status Byte value
Yn	Test bit n of the Status Byte
Z	Reset to default settings and cancel all pending commands.

Status Byte Definition

Bit Meaning

0 Magnitude too small to calculate
   phase
1 Command Parameter is out-of-range
2 No detectable reference input
3 PLL is not locked to the reference
4 Signal Overload
5 Auto-offset failed: signal too large
6 SRQ generated
7 Unrecognized or illegal command

Configuration Switches

There are two banks of 8 switches, SW1 and SW2, located on the rear panel. SW1 sets the GPIB address and SW2 sets the RS232 parameters. The configuration switches are read continuously and any changes will be effective immediately.

SW1:GPIB Mode Switches

Bit	Example	Function
1 }	up	GPIB Address Switches
2 }	up	Address 0 to 30 allowed
3 }	up	'up' for bit = 1
4 }	down	'down' for bit = 0
5 }	up	(Most Significant Bit)
6	down	'down' to echo on RS232 (normally 'up')
7	up	Not Used
8	up	Not Used

If the GPIB mode switches are set as shown in the example column above, then the lockin will be addressed as GPIB device #23, and all GPIB commands and data will be echoed over the RS232 for de-bugging purposes.

SW2:RS232 Mode Switches

Bit 1	Bit 2	Bit 3	Baud Rate
up	up	up	19200
down	up	up	9600
up	down	up	4800
down	down	up	2400
up	up	down	1200
down	up	down	600
up	down	down	300

Bit	Setting	Explanation
4	up	Odd parity
	down	Even parity
5	up	No parity
	down	Parity enabled
6	up	No echo (for computer)
	down	Echo mode (for terminal)
7	up	Two stop bits
	down	One stop bit
8		unused

Eight data bits are always sent, regardless of the parity setting. The most significant bit is always zero.

Example: Bit 1 'down' and all others 'up' for RS232 communication at 9600 baud, no parity, two stop bits, and no echo or prompts by the SR530.

SR510 Guide to Operation
Front Panel

The front panel has been designed to be almost self-explanatory. The effect of each keypress is usually reflected in the change of a nearby LED indicator or by a change in the quantity shown on a digital display. This discussion explains each section of the front panel, proceeding left to right.

Signal Inputs

There are three input connectors located in the **SIGNAL INPUT** section of the front panel. The rocker switch located above the **B** input selects the input mode, either single-ended, **A**, differential, **A-B**, or current, **I**.

The **A** and **B** inputs are voltage inputs with 100 MΩ, 25 pF input impedance. Their connector shields are isolated from the chassis ground by 10Ω. These inputs are protected to 100V dc but the ac input should never exceed 10V peak. The maximum ac input before overload is 1V peak.

The **I** input is a current input with an input impedance of 1 KΩ to a virtual ground. The largest allowable dc current before overload is 1 μA. No current larger than 10 mA should ever be applied to this input. The conversion ratio is 10^6 V/A, thus, the full scale current sensitivities range from 100 fA to 500 nA with a max ac input before overload of 1 μA peak. You should use short cables when using the current input.

Signal Filters

There are three user selectable signal filters available; a line frequency notch, a 2X line frequency notch, and an auto-tracking bandpass. Each of the filters has a pair of indicator LED's and a function key located in the **SIGNAL FILTERS** section of the front panel. Pressing a key will toggle the status of the appropriate filter. The status of each filter is displayed as **IN**, filter active, or **OUT**, filter inactive.

The notch filters have a Q of 10 and a depth of at least 50 dB. Thus, the line frequency notch is 6 Hz wide and the 2X line notch has a width of 12 Hz. Both of these filters can increase the dynamic reserve up to 50 dB at the notch frequencies. The achievable reserve is limited by the maximum allowable signals at the inputs. The notch frequencies are set at the factory to either 50 Hz or 60 Hz. The user can adjust these frequencies. (See the Maintenance and Repair section for alignment details.) These filters precede the bandpass filter in the signal amplifier.

The bandpass filter has a Q of 5 and a 6 dB roll off in either direction. Thus, the pass band (between 70% pass points) is always equal to 1/5th of the center frequency. The center frequency is continually adjusted to be equal to the internal demodulator frequency. When the reference mode is f, the filter tracks the reference. When the mode is 2f, the filter frequency is twice the reference input frequency. The center frequency tracks as fast as the reference oscillator can slew and may be used during frequency scans. The bandpass filter adds up to 20 dB of dynamic reserve for noise signals outside the pass band, and increases the harmonic rejection by at least 13dB. (2nd harmonic attenuated by 13 dB, higher harmonics attenuated 6dB/octave more.) If not needed to improve the dynamic reserve or the harmonic rejection then the filter should be left **OUT**.

Sensitivity

The sensitivity is displayed as a value (1-500) and a scale (nV, μV, mV). When using the current input, which has a gain of 10^6 V/A, these scales read fA, pA, and nA. The two keys in the **SENSITIVITY** section move the sensitivity up and down. If either key is held down, the sensitivity will continue to change in the desired direction four times a second.

The full scale sensitivity can range from 100 nV to 500 mV. The sensitivity indication is not changed by the **EXPAND** function. The **EXPAND** function increases the output sensitivity (Volts out /volts in) as well as the resolution of the digital output display.

Not all dynamic reserves are available at all sensitivities. If the sensitivity is changed to a setting for which the dynamic reserve is not allowed, the dynamic reserve will change to the next setting which is allowed. Sensitivity takes precedence over the dynamic reserve. The sensitivity range of each dynamic reserve is shown below.

Dynamic Reserve	Sensitivity Range
LOW	1 µV through 500 mV
NORM	100 nV through 50 mV
HIGH	100 nV through 5 mV

Dynamic Reserve

The dynamic reserve (DR) is set using the keys in the **DYNAMIC RESERVE** section. The reserve is displayed by the three indicator LED's, **HIGH**, **NORM**, **LOW**. Only those dynamic reserve settings available for the sensitivity are allowed (see above table). For example, when the sensitivity is 500 mV, the DR will always be **LOW**.

The dynamic reserve and output stability of each setting are shown below.

Setting	Dynamic Reserve	Output Stability (ppm/°C)
LOW	20 dB	5
NORM	40 dB	50
HIGH	60 dB	500

Since a higher DR results in degraded output stability, you should use the lowest DR setting for which there is no overload indication. Note that using the Bandpass Filter provides about 20dB of additional DR and so allows you to operate with a lower DR setting.

Status

There are five STATUS LED's.

OVLD indicates a signal overload. This condition can occur when the signal is too large, the sensitivity is too high, the dynamic reserve is too low, the offset is on, the expand is on, the time constant is not large enough, or the ENBW is too large.

The **OVLD** LED blinks four times a second when an output is overloaded. This occurs if an output exceeds full scale. For example, during a quadrature measurement where X exceeds full scale while Y is near zero, a blinking **OVLD** indicates that it is safe to take data from the Y output since only the X output is overloaded. The signal path to the Y output is not overloaded. **OVLD** also blinks if a noise measurement is attempted on an output which exceeds full scale.

If the **OVLD** LED is on continuously or flashes randomly, then an overload has occurred before the output, i.e. in the ac amplifier or output time constant. In this case, the dynamic reserve, sensitivity, time constant, or ENBW needs to be adjusted.

UNLK indicates that the reference oscillator is not phase locked to the external reference input. This can occur if the reference amplitude is too low, the frequency is out of range, or the trigger mode is incorrect for the reference signal waveform.

ERR flashes when an error occurs on one of the computer interfaces, such as an incorrect command, invalid parameter, etc.

ACT indicates activity on the computer interfaces. This LED blinks every time a character is received or transmitted by the SR530.

REM indicates that the unit is in the remote state and that the front panel controls are not operative. There are two remote states. The Remote-With-Lockout will not allow any inputs from the front panel. The Remote-Without-Lockout command allows you to return the front panel to operation by pressing the **LOCAL** key.

Display Select

The keys in the **DISPLAY** section select the parameters to be displayed on the **OUTPUT METERS** and the output of the two **OUTPUT BNC** connectors. The displayed parameters are indicated by one of the six **DISPLAY LED**'s and can be either the two demodulator outputs (**X Y**), the demodulator output offsets (**X OFST Y OFST**), the magnitude and phase (**R Ø**), the magnitude offset and phase (**R OFST Ø**), the rms noise on X and Y (**X NOISE Y NOISE**), or the D/A outputs (**X5 D/A X6**). When displaying **NOISE**, the equivalent noise bandwidth is selected in the **TIME CONSTANT** section. When displaying **D/A**, the 2 outputs are the **X5** and **X6** rear panel D/A outputs, allowing the D/A outputs to be set from the front panel. This feature can be used to set the reference frequency when using the internal oscillator.

Channel 1 Display

The channel 1 outputs are summarized below. X is equal to RcosØ where Ø is the phase shift of the signal relative to the reference oscillator of the lock-in.

10

display setting	CH1 output	expand?	offset?	X (RCOSØ)
X	$X+X_{ofst}$	yes	yes	$X+X_{ofst}$
XOFST	X_{ofst}	yes	yes	X_{ofst}
R	$R+R_{ofst}$	yes	yes	$X+X_{ofst}$
R OFST	R_{ofst}	yes	yes	$X+X_{ofst}$
XNOISE	X noise	yes	yes	$X+X_{ofst}$(enbw)
X5	X5	no	adjust	$X+X_{ofst}$

The **EXPAND** and **OFFSET** conditions for each display are retained when the **DISPLAY** is changed. Thus, when the **DISPLAY** is changed from **X** to **R**, the **EXPAND** and **OFFSET** assume the conditions set the last time the **DISPLAY** was **R**. If the **DISPLAY** is changed back to **X**, the **EXPAND** and **OFFSET** return to conditions set for **X**.

R Output

The magnitude, R, is given by the equation:

$$R = \{(X+X_{ofst})^2 + (Y+Y_{ofst})^2\}^{1/2} + R_{ofst}$$

Note that the X and Y offsets affect the value of R while the X and Y expands do not.

The magnitude output has a resolution of 12 bits plus sign and is updated every 3.5 mS. To achieve maximum accuracy, the magnitude should be as large a fraction of full scale as possible.

R is expanded after the calculation. Thus, when R is expanded, the full scale resolution drops by a factor of 10 to about 9 bits.

Output Channel 1

The **CHANNEL 1** output is available at the left hand **OUTPUT BNC** connector. The output parameter is selected by the **DISPLAY** setting and can be **X**, **X OFST**, **R** (magnitude), **R OFST**, **X NOISE**, or **X5** (external D/A). (Note that **X5** is the ratio output at power up. When displaying **X5**, the ratio output is 10R/X1). All outputs are ±10V full scale when the **EXPAND** is off. With the **EXPAND** on, the output is multipled by 10 effectively increasing the full scale sensitivity by 10. (**X5** may not be expanded). The output impedance is < 1Ω and the output current is limited to 20 mA.

The left hand analog meter always displays the **CHANNEL 1 OUTPUT** voltage. Accuracy is 2% of full scale.

The **CHANNEL 1 LCD** display provides a read-out of the displayed parameter in real units. The scale of the displayed quantity is indicated by the three scale LED's to the left of the display. This read-out auto ranges and will reflect the sensitivity added when the **EXPAND** function is on. When displaying **X5**, the scale LED's are off and the units are volts.

Rel Channel 1

Every time the **REL** key is pressed, the displayed parameter is offset to zero. This is done by loading the displayed parameter's offset with minus one times the present output. If the output is greater than 1.024 times full scale, the **REL** function will not be able to zero the output. In this case, the **OFFSET ON** LED will blink and the offset value will be set to its maximum value.

The **REL** function and the manual **OFFSET** are both ways to enter the offset value. After using the **REL** key, the offset may be adjusted using the manual **OFFSET**.

When the **DISPLAY** is **X**, **X OFST**, or **X NOISE**, the **REL** key sets the X OFFSET (which affects the **X (RCOSØ)** output). If **X NOISE** is being displayed, the **REL** function zeroes **X** and the noise output will require a few seconds to settle again.

When the **DISPLAY** is **R** or **R OFST**, the **REL** key sets the R OFFSET.

The **REL** key zeroes the **X5** output when the **DISPLAY** is **D/A**.

Offset Channel 1

The **OFFSET** buttons control the manual offset. The offset is turned **ON** and **OFF** using the upper key in the **OFFSET** section. When the offset is **ON**, the lower two keys are used to set the amount of offset. A single key press will advance the offset by 0.025% of full scale. If the key is held down, the offset advances in larger and larger increments, the largest increment being 10% of full scale. When the offset is turned **OFF** the applied offset returns to zero but the offset value is not lost. The next press of the upper offset key (return

to **ON**) sets the offset to the previously entered value.

If an attempt is made to advance the offset value beyond full scale, the **ON** LED will blink. An offset up to 1.024 times the full scale sensitivity may be entered. When the **EXPAND** is on, this is 10X the full scale output.

Note that the offsets (either manual offset or those generated by the **REL** function) represent a fraction of the full scale reading, and so their absolute value will change when the sensitivity scale is changed. A signal which has been nulled by an offset will not be nulled when the sensitivity scale is changed. The analog meter and the output BNC indicate the same value given by the equation:

$$V_{out} = 10A_e(A_vV_i cos\emptyset + V_{os})\ \{\text{if the output is X}\}$$

where...

A_e = 1 or 10 per the Expand
A_v = 1/Sensitivity
V_i = magnitude of the signal
$\emptyset$ = phase between signal & reference
V_{os} = offset (fraction of FS < 1.024)

When the **DISPLAY** is **X**, **X OFST**, or **X NOISE**, the **OFFSET** keys adjust the X OFFSET (which affects the **X (RCOSØ)** output). When the **DISPLAY** is **R** or **R OFST**, the **OFFSET** keys adjust the R OFFSET. When the **DISPLAY** is **X5**, the **OFFSET** up and down keys set the output voltage of D/A output **X5** (also on the rear panel) up to ±10.24 V. Adjusting **X5** will cancel the **RATIO** output.

Expand Channel 1

The output **EXPAND** is toggled by pressing the key in the Channel 1 **EXPAND** section. The expand status is indicated by the **X10**, expand on, and the **X1**, expand off, LED's. Only the Channel 1 **OUTPUT** is affected, the **X (RCOSØ)** output is not expanded.

The **X5** D/A output may not be expanded.

X (RCOSØ) Output

The analog output, X+X$_{ofst}$, is available at the **X (RCOSØ)** BNC connector. An input signal equal in magnitude to the selected sensitivity which is in phase with the reference oscillator will generate a 10V output. The output impedance is <1Ω and the output current is limited to 20 mA.

The **X (RCOSØ)** output is affected by the X offset but may not be expanded. The **X (RCOSØ)** is not affected by the **DISPLAY** setting except for two cases. When the **DISPLAY** is set to **X OFST**, the **X (RCOSØ)** output is the X offset. When the **DISPLAY** is set to **X NOISE**, the **X (RCOSØ)** output has a bandwidth equal to the ENBW (1 or 10 Hz) instead of the time constant.

Channel 2 Display

The channel 2 outputs are summarized below. Y is equal to RsinØ where Ø is the phase shift of the signal relative to the reference oscillator of the lock-in.

display setting	CH2 output	expand?	offset?	Y (RSINØ)
Y	Y+Y$_{ofst}$	yes	yes	Y+Y$_{ofst}$
YOFST	Y$_{ofst}$	yes	yes	Y$_{ofst}$
Ø	Phase	no	no	Y+Y$_{ofst}$
Ø	Phase	no	no	Y+Y$_{ofst}$
YNOISE	Y noise	yes	yes	Y+Y$_{ofst}$(enbw)
X6	X6	no	adjust	Y+Y$_{ofst}$

The **EXPAND** and **OFFSET** conditions for each display are retained when the **DISPLAY** is changed. Thus, when the **DISPLAY** is changed from **Y** to **Ø**, the **EXPAND** and **OFFSET** turn off. If the **DISPLAY** is changed back to **Y** the **EXPAND** and **OFFSET** return to conditions set for **Y**.

Ø Output

The phase, Ø, is given by the equation:

$$\emptyset = -\tan^{-1}\{(Y+Y_{ofst})/(X+X_{ofst})\}$$

Note that the X and Y offsets affect the value of Ø while the X and Y expands do not.

The Phase Output voltage is 50 mV per degree with a resolution of 2.5 mV or 1/20 of a degree. The output range is from -180 to +180 degrees. The phase output is updated every 3.5 mS. To achieve maximum accuracy, the magnitude, R, should be as large a fraction of full scale as

possible. If R is less than 0.5% of full scale, the phase output defaults to zero degrees.

The Phase Output may not be expanded and the **OFFSET** keys do not offset the Phase Output. However, the Phase Output can be offset using the Reference Phase shift.

The Reference Phase shift, which may be adjusted via the phase controls in the reference section, rotates the lock-in's internal coordinate axes relative to the reference input. The Phase Output is the phase difference between the signal and the lock-in's coordinate system. For example, if a signal exactly in phase with the reference input is being measured and the Reference Phase shift is zero, the Phase Output will be zero also. This is because the lock-in coordinate system is in phase with the reference input and signal. If the Reference Phase shift is set to +45 degrees, then the lock-in coordinate system rotates to +45 degrees from the reference input. Thus, the reference input is now at -45 degrees from the lock-in coordinate axes. Since the reference and signal are in phase, the signal is now at -45 degrees with respect to the lock-in coordinates and the Phase Output will be -45 degrees.

The sum of the Reference Phase shift and the Phase Output is the absolute phase difference between the signal and the reference input. Therefore, the Phase Output may be offset to zero by adjusting the Reference Phase shift. This is sometimes necessary when the Phase Output is near 180 degrees and varies between +180 and -180 degrees.

Output Channel 2

The **CHANNEL 2** output is available at the right hand **OUTPUT BNC** connector. The output parameter is selected by the **DISPLAY** setting and can be **Y**, **Y OFST**, **Ø** (phase), **Ø** (phase), **Y NOISE**, or **X6** (ext D/A). All outputs are ±10V full scale when the **EXPAND** is off. With the **EXPAND** on, the output is multipled by 10, effectively increasing the full scale sensitivity by 10. (**Ø** and **X6** may not be expanded). The **Ø** (phase) output is 50 mV/deg (20 deg per Volt) up to ±9 V (±180 deg). The output impedance is <1Ω and the output current is limited to 20 mA.

The right hand analog meter always displays the **CHANNEL 2 OUTPUT** voltage. Accuracy is 2% of full scale.

The **CHANNEL 2 LCD** display provides a read-out of the displayed parameter in real units. The scale of the displayed quantity is indicated by the four scale LED's to the right of the display. This read-out auto ranges and will reflect the sensitivity added when the **EXPAND** function is on. When displaying **X6**, the scale LED's are off and the units are volts.

Rel Channel 2

Every time the **REL** key is pressed, the displayed parameter is offset to zero. This is done by loading the displayed parameter's offset with minus one times the present output. If the output is greater than 1.024 times full scale, the **REL** function will not be able to zero the output. In this case, the **OFFSET ON** LED will blink and the offset value will be set to its maximum value.

The **REL** function and the manual **OFFSET** are both ways to enter the offset value. After using the **REL** key, the offset may be adjusted using the manual **OFFSET**.

When the **DISPLAY** is **Y**, **Y OFST**, or **Y NOISE**, the **REL** key sets the Y OFFSET (which affects the **Y (RSINØ)** output). If **Y NOISE** is being displayed, the **REL** function zeroes **Y** and the noise output will require a few seconds to settle again.

The **REL** key zeroes the **X6** output when the **DISPLAY** is **D/A**.

Auto Phase

When the **DISPLAY** is **Ø** (phase), the **REL** key sets the Reference Phase Shift to the absolute phase difference between the signal and the reference. This is done by setting the Reference Phase Shift to the sum of the Reference Phase Shift and the present Phase Output. After auto-phase is performed, the Ø output will be 0 deg, R will be unchanged, X will be maximized, and Y will be minimized.

Offset Channel 2

The **OFFSET** section controls the manual offset. The offset is turned **ON** and **OFF** using the upper key in the **OFFSET** section. When the offset is **ON**, the lower two keys are used to set the amount of offset. A single key press will advance the offset by 0.025% of full scale. If the key is held

down, the offset advances in larger and larger increments, the largest increment being 10% of full scale. When the offset is turned **OFF** the applied offset returns to zero but the offset value is not lost. The next press of the upper offset key (return to **ON**) sets the offset to the previously entered value.

If an attempt is made to advance the offset value beyond full scale, the **ON** LED will blink. An offset up to 1.024 times the full-scale sensitivity may be entered. When the **EXPAND** is on, this is 10X the full scale output.

Note that the offsets (either manual offset or those generated by the **REL** function) represent a fraction of the full scale reading, and so their absolute value will change when the sensitivity scale is changed. A signal which has been nulled by an offset will not be nulled when the sensitivity scale is changed. The analog meter and the output BNC indicate the same value given by the equation:

$$V_{out} = 10A_e(A_vV_i sin\emptyset + V_{os}) \text{ \{if the output is Y\}}$$

where...
   A_e =   1 or 10 per the Expand
   A_v =   1/Sensitivity
   V_i =   magnitude of the signal
   Ø   =   phase between signal & reference
   V_{os} =   offset (fraction of FS < 1.024)

When the **DISPLAY** is **Y**, **Y OFST**, or **Y NOISE**, the **OFFSET** keys adjust the Y OFFSET (which affects the **Y (RSINØ)** output). When the **DISPLAY** is **Ø**, the **OFFSET** keys do nothing. When the **DISPLAY** is **X6**, the **OFFSET** up and down keys set the output voltage of D/A output **X6** (also on the rear panel) up to ±10.24V.

Expand Channel 2

The output **EXPAND** is toggled by pressing the key in the Channel 2 **EXPAND** section. The expand status is indicated by the **X10**, expand on, and the **X1**, expand off, LED's. Only the Channel 2 **OUTPUT** is affected, the **Y (RSINØ)** output is not expanded. **Ø** and **X6** may not be expanded.

Y (RSINØ) Output

The analog output, Y+Y$_{ofst}$, is available at the **Y (RSINØ)** BNC connector. An input signal equal in magnitude to the selected sensitivity which is 90° out of phase with the reference oscillator will generate a 10V output. The output impedance is <1Ω and the output current is limited to 20 mA.

The **Y (RSINØ)** output is affected by the Y offset but may not be expanded. The **Y (RSINØ)** is not affected by the **DISPLAY** setting except for two cases. When the **DISPLAY** is set to **Y OFST**, the **Y (RSINØ)** output is the Y offset. When the **DISPLAY** is set to **Y NOISE**, the **Y (RSINØ)** output has a bandwidth equal to the ENBW (1 or 10 Hz) instead of the time constant.

Reference Input

The **REFERENCE INPUT** BNC is located in **REFERENCE INPUT** section. The input is ac coupled and the impedance is 1 MΩ. The dc voltage at this input should not exceed 100 V and the largest ac signal should be less than 10 V peak.

Trigger Level

The **TRIGGER MODE** indicator toggles from **POSITIVE** to **SYMMETRIC** to **NEGATIVE** when the **TRIGGER MODE** key is pressed.

If the center **TRIGGER MODE** LED is on, the mode is **SYMMETRIC** and the reference oscillator will lock to the positive zero crossings of the ac reference input. The ac signal must be symmetric (e.g. sine wave, square wave, etc.) and have a peak to peak amplitude greater than 100 mV. A signal with 1 Vrms amplitude is recommended. The phase accuracy of the reference channel is specified for a 1Vrms sinewave in the symmetric trigger mode.

If the upper **TRIGGER MODE** LED is on, the mode is **POSITIVE**. The trigger threshold is +1V and the reference oscillator will lock to the positive going transitions of the reference input. This mode triggers on the rising edges of a TTL type pulse train. The pulse width must be greater than 1 μS.

If the lower **TRIGGER MODE** LED is on, the mode is **NEGATIVE**. The trigger threshold is -1V and the reference oscillator will lock to the negative

going transitions of the reference input. This mode triggers on a negative pulse train or on the falling edges of a TTL type pulse train (remembering that the input is ac coupled). The pulse width must be greater than 1 μS.

Reference Mode

The **REFERENCE MODE** indicator toggles between **f** and **2f** whenever the **MODE** key is pressed. When the **MODE** is **f**, the lock-in will detect signals at the reference input frequency. When the **MODE** is **2f**, the lock-in detects signals at twice the reference input frequency. In either case, the reference oscillator has a maximum frequency of 100 KHz, thus, when in the **2f** mode, the reference input frequency may not exceed 50 KHz.

Reference Display

The **REFERENCE DIGITAL DISPLAY** shows either the reference oscillator frequency or phase shift. The displayed parameter toggles between the two whenever the **SELECT** key is pressed. The appropriate scale indicator below the display will be on. It is useful to check the frequency display to verify that the lock-in has correctly locked to your reference. The reference frequency is measured to 1 part in 256 resolution at all frequencies. The display reads .000 if there is no reference input and 199.9 kHz if the input frequency exceeds 105 kHz.

Phase Controls

The phase shift between the reference oscillator of the lock-in and the reference input signal is set using the four keys in the **PHASE** section. The two keys below the **FINE** label increment the phase setting in small amounts. A single key press will change the phase by 0.025 degrees in the desired direction. Holding the key down will continue to change the phase with larger and larger steps with the largest step being 10 degrees. The two **90°** keys are used to change the phase by 90 degree increments. The upper key will add 90 degrees and the lower key will subtract 90 degrees. Holding both keys down at once sets the phase shift back to zero. The **REFERENCE DIGITAL DISPLAY** automatically displays the phase whenever any of the **PHASE** keys are pressed. The phase ranges from -180 degrees to +180 degrees and is the phase delay from the reference input signal.

Time Constant

There are two post demodulator low pass filters, labeled **PRE** and **POST**. The **PRE** filter precedes the **POST** filter in the output amplifier. Each filter provides 6 dB/oct attenuation.

The **PRE** filter time constant ranges from **1 mS** to **100 S** and is selected by the two keys below the **PRE** filter indicator LED's. Holding down either key will advance the time constant four times a second in the desired direction.

In many servo applications, no time constant is needed. The SR530 may be modified to reduce the output time constant to about 20 μS. Contact the factory for details.

The **POST** filter time constant can be set to **1 S** or **0.1 S**, or can be removed altogether, **NONE**, using the two keys below the **ENBW** indicators. When set to **NONE**, the total attenuation is that of the **PRE** filter, or 6 dB/oct. When the **POST** filter is **1 S** or **0.1S**, the total attenuation is 12 dB/oct for frequency components beyond the larger of the **POST** and **PRE** filter bandwidths (reciprocal time constant).

Noise Measurements

When the **DISPLAY** is set to **X NOISE Y NOISE**, none of the **PRE** and **POST** indicator LED's are on. Instead, one of the two **ENBW** indicators will be on, showing the Equivalent Noise Bandwidth of the rms noise calculation. The **ENBW** is set using the keys below the **ENBW** indicator LED's (same keys as used to set the **POST** filter). The **PRE** filter keys do nothing in this case. Pressing the upper key when the bandwidth is already **1 Hz** will reset the rms noise average (output) to zero, restarting the calculation. Likewise with pressing the lower key when **10 Hz** is already selected.

The noise is the rms deviation of the output within a 1 or 10 Hz equivalent noise bandwidth about the reference frequency. A dc output does not contribute to the noise, the noise is determined only by the ac 'wiggles' at the output. By measuring the noise at different frequencies, the frequency dependence of the noise density can be found. This usually has the form of $v_{noise} \sim 1/f$.

The noise computation assumes that the noise has a Gaussian distribution (such as Johnson noise). Since the computation takes many time constants (reciprocal ENBW), the noise output

should be allowed to approach a steady value before a reading is taken. For the 1 Hz ENBW, this time is on the order of 15 to 30 seconds; for the 10 Hz ENBW, the output stabilizes much faster. The noise output will vary slightly since there will always be noise variations that are slow compared to the bandwidth. Any DC component in the output will not contribute to the noise. However, a large DC output will cause the noise computation to initially rise to a large value before approaching the final answer. As a result, the computation will take longer to settle.

If the **OVLD** indicator is blinking four times a second, then either the X or Y output is overloaded and the corresponding noise calculation should be ignored. If the **OVLD** LED is on continuously, then the input signal is overloading the ac amplifier or time constant filters. In this case, both noise outputs will be wrong.

To obtain a value for the noise density, the noise reading should be divided by the square root of the ENBW. Thus, when the ENBW is 1 Hz, the noise output is the noise density, and when the ENBW is 10 Hz, the noise density is the noise output divided by $\sqrt{10}$. For example, if the input noise is measured to be 7 nV with the ENBW set to 1 Hz, the noise density is 7 nV/$\sqrt{Hz}$. Switching the ENBW to 10 Hz results in a faster measurement and a reading of 22 nV on the output. The noise density is 22 nV/$\sqrt{10}$ Hz or 7 nV/$\sqrt{Hz}$. At frequencies » 10 Hz, the noise density should be independent of the ENBW.

Power

This is the instrument's **POWER** switch. When the power is turned off, the front panel settings are retained so that the instrument will return to the same settings when the power is next turned on. The SR530 always powers up in the **LOCAL** mode.

The D/A outputs **X5** and **X6** are not retained during power off. **X5** always becomes the **RATIO** output at power on and **X6** is always reset to zero.

When the power is turned on, the **CHANNEL 1 OUTPUT DIGITAL DISPLAY** will show the **SERIAL NUMBER** of the instrument and the **CHANNEL 2 OUTPUT DIGITAL DISPLAY** will show the firmware **VERSION**. The **REFERENCE DIGITIAL DISPLAY** shows the model number of the instrument. All displays return to normal after 3 seconds.

Local and Remote

When the instrument is programmed via the computer interface to be in the **REMOTE** state **WITHOUT LOCK-OUT**, the **LOCAL** key will return the instrument to **LOCAL** front panel control. If the instrument is in the **REMOTE WITH LOCK-OUT** state, no front panel key will return the status to **LOCAL**. In this case, a **RETURN TO LOCAL** command must be sent over the computer interface or the power must be turned off and back on.

Defaults

If the **LOCAL** key is held down when the **POWER** is turned on, the instrument settings will be set to the defaults shown below instead of the settings in effect when the power was turned off.

Parameter	Setting
BANDPASS	OUT
LINE	OUT
LINE X 2	OUT
SENSITIVITY	500 mV
DYN RES	LOW
DISPLAYS	X Y
EXPANDS	OFF
OFFSETS	OFF (value=0)
PRE TIME CONSTANT	100 mS
POST TIME CONSTANT	0.1 S
ENBW	1 Hz
REFERENCE MODE	f
TRIGGER MODE	SYMMETRIC
REFERENCE DISPLAY	FREQUENCY
PHASE SHIFT	0°

Whenever default values are used at power up, the red **ERR** LED will turn on for about 3 seconds. If the **ERR** LED is on when the instrument is powered on without the **LOCAL** key down, then the instrument is ignoring the retained settings. This can be due to a low battery.

SR530 Guide to Operation
Rear Panel

AC Power

The ac line voltage selector card, line fuse, and line cord receptacle are located in the fuse holder at the left side of the rear panel. See the section, **Preparation for Use** at the front of this manual for instructions on setting the ac voltage selector and choosing the correct fuse.

GPIB Connector

The SR530 has an IEEE 488 (GPIB) interface built in. The GPIB address is set using **SW1** located to the right of the interface connectors. Refer to page 7 for switch setting details.

RS232 Connector

The SR530 has an RS232 interface. The connector is configured as a **DCE**. The baud rate, parity, stop bits, and echo mode are selected using **SW2** located to the right of the interface connectors. Refer to Page 7 for switch setting details.

Signal Monitor Output

This BNC provides the buffered output of the signal amplifiers and filters. This is the signal just before the demodulator. The output impedance is <1Ω. When a full scale input is applied, the peak-to-peak amplitude at this output is 20 mV, 200 mV or 2 V for dynamic reserve settings of high, norm, and low, respectively.

Preamp Connector

This 9 pin "D" connector provides power and control signals to external peripherals such as pre-amplifiers. The available power is described below.

Pin	Voltage	Current Available
1	+20	100 mA
2	+5	10 mA
6	-20	100 mA
7		Signal ground
8		Digital ground

General Purpose A/D and D/A

There are four analog input ports, labeled **X1** through **X4**. These inputs may be digitized and read via the computer interfaces. The range is -10.24 V to +10.24 V and the resolution is 2.5 mV. The input impedance is 1 MΩ. A digitization can be performed in about 3 mS but the result may take longer to transmit over the interface being used.

There are two analog output ports, labeled **X5** and **X6**. The voltages at these ports may be programmed via the computer interfaces. The range is -10.24 V to +10.24 V and the resolution is 2.5 mV. The output impedance is <1Ω and the output current is limited to 20 mA.

Ratio

Output **X5** is the ratio output when not programmed by the computer interface or set via the front panel. **X5** becomes the ratio output whenever the unit is turned on.

The voltage at **X5** is the ratio of the Channel 1 Output to the analog voltage at port **X1**. An output of 10 V corresponds to a ratio of 1. The ratio is computed by digitizing the Channel 1 Output and the voltage at port **X1** and then taking the ratio. The resolution is 2.5 mV. For best accuracy, the sensitivity should be set to provide at least a 50% full scale signal and the analog denominator (**X1**) should be 5V or greater. The ratio is updated approximately every 3 mS. For the Ratio feature to work, the voltage at the denominator input must exceed 40 mV.

When the **DISPLAY** is set to **D/A**, the ratio output is 10 times the magnitude, **R**, divided by **X1**.

Internal Oscillator

The **INTERNAL OSCILLATOR** is a voltage controlled oscillator with a sine wave output . To use the oscillator as the reference source, connect

the **REF OUTPUT** on the rear panel to the **REF INPUT** on the front panel. The **REF OUTPUT** is a 1 Vrms sine wave. The **SINE OUTPUT** may be used as the stimulus to the experiment. The **SINE OUTPUT** can be set to three amplitudes, 1 V, 100 mV, and 10 mV (rms) using the amplitude switch. The output impedance is 600Ω. The **AMP CAL** screw adjusts the amplitude.

The oscillator frequency is controlled by the **VCO INPUT** voltage. A voltage from 0V to 10V will adjust the frequency according to the **VCO RANGE** selected. Three ranges are available, 1 Hz/V, 100 Hz/V, and 10 KHz/V. The input impedance is 10 kΩ. The **FREQUENCY CAL** screw adjusts the frequency.

There are four ways to set the frequency:

1) Connect **X5** or **X6** (D/A outputs) to the **VCO INPUT**. The frequency can now be set from the front panel by setting the **DISPLAY** to **D/A** and adjusting **X5** or **X6**. The frequency is also controllable via the computer interfaces by programming **X5** or **X6**.

2) If the **VCO INPUT** is left open, then the oscillator will run at the top of its range (i.e. 10 Hz, 1 KHz, or 100 KHz).

3) A 10 KΩ potentiometer may be connected from the **VCO INPUT** to ground. This pot will then set the frequency.

4) Connect the VCO INPUT to an external voltage source which can provide 0 to 10V.

In all four cases, if the **REF OUTPUT** is connected to the **REFERENCE INPUT** on the front panel, the frequency may be read on the front panel **REFERENCE DIGITAL DISPLAY** or via the computer interfaces.

SR530 Guide to Programming

The SR530 Lock-in Amplifier is remotely programmable via both RS232 and GPIB interfaces. It may be used with laboratory computers or simply with a terminal. All front panel features (except signal input selection and power) may be controlled and read via the computer interfaces. The SR530 can also read the analog outputs of other laboratory instruments using its four general purpose analog input ports. There are also two programmable analog output ports available to provide general purpose control voltages.

Communicating with the SR530

Before using either the RS232 or GPIB interface, the appropriate configuration switches need to be set. There are two banks of 8 switches, **SW1** and **SW2**, located on the rear panel. **SW1** sets the GPIB address and **SW2** sets the RS232 parameters. The configuration switches are read continuously and any changes will be effective immediately. For details on switch settings, see page 7 at the front of this manual.

Command Syntax

Communications with the SR530 use ASCII characters. Commands to the SR530 may be in either UPPER or lower case.

A command to the SR530 consists of one or two command letters, arguments or parameters if necessary, and an ASCII carriage return (<cr>) or line-feed (<lf>) or both. The different parts of the command do not need to be separated by spaces. If spaces are included, they will be ignored. If more than one parameter is required by a command, the parameters must be separated by a comma. Examples of commands are:

G 5 <cr>   set the sensitivity to 200 nV
T 1,4 <cr>   set the pre filter to 30 mS
F <cr>   read the reference frequency
P 45.10 <cr>   set phase shift to 45.10¡
X 5,-1.23E-1 <cr>   set port X5 to -0.123 V

Multiple commands may be sent on a single line. The commands must be separated by a semicolon (;) character. The commands will not be executed until the terminating carriage return is sent.

An example of a multiple command is:

G 5; T 1,4; P 45.10 <cr>

It is not necessary to wait between commands. The SR530 has a command input buffer of 256 characters and processes the commands in the order received. Likewise, the SR530 has an output buffer (for each interface) of 256 characters.

In general, if a command is sent without parameters, it is interpreted as a request to read the status of the associated function or setting. Values returned by the SR530 are sent as a string of ASCII characters terminated usually by carriage return, line-feed. For example, after the above command is sent, the following read commands would generate the responses shown below.

Command	Response from the SR530
G <cr>	5<cr><lf>
T 1 <cr>	4<cr><lf>
P <cr>	45.10<cr><lf>

The choice of terminating characters sent by the SR530 is determined by which interface is being used and whether the 'echo' feature is in use. The terminating sequence for the GPIB interface is always <cr><lf> (with EOI). The default sequence for RS232 is <cr> when the echo mode is off, and <cr><lf> when the echo mode is on. The terminating sequence for the RS232 interface may be changed using the J command.

Note that the terminating characters are sent with each value returned by the SR530. Thus, the response to the command string G;T1;P<cr> while using the RS232 non-echo mode would be 5<cr>4<cr>45.10<cr>.

Front Panel Status LED's

The **ACT** LED flashes whenever the SR530 is sending or receiving characters over the computer interfaces.

The **ERR** LED flashes whenever an error has occurred, such as, an illegal command has been received, a parameter is out of range, or a communication buffer has exceeded 240 characters. This LED flashes for about three seconds on power-up if the battery voltage is insufficient to retain previous instrument settings.

The **REM** LED is on whenever the SR530 is programmed to be in the remote state.

RS232 Echo and No Echo Operation

In order to allow the SR530 to be operated from a terminal, an echo feature has been included which causes the unit to echo back commands received over the RS232 port. This feature is enabled by setting switch 6 on **SW2** to the DOWN position. In this mode, the SR530 will send line-feeds in addition to carriage returns with each value returned and will also send the prompts 'OK>' and '?>' to indicate that the previous command line was either processed or contained an error. Operating the SR530 from a terminal is an ideal way to learn the commands and responses before attempting to program a computer to control the SR530. When the unit is controlled by a computer, the echo feature should be turned off to prevent the sending of spurious characters which the computer is not expecting.

Try-Out with an ASCII Terminal

Before attempting any detailed programming with the SR530, it is best to try out the commands using a terminal. Connect a terminal with an RS232 port to the RS232 connector on the rear panel of the SR530. A 'straight' RS232 cable is required since the SR530 is a DCE and the terminal is a DTE. Set the baud rate, parity, and stop bits to match the terminal by setting **SW2** per the switch setting table given on page 7. The echo mode should be enabled (switch 6 DOWN). After setting **SW2** and connecting the terminal, hold down the **LOCAL** key while turning the unit on. This causes the SR530 to assume its default settings so that the following discussion will agree with the actual responses of the SR530. The **ACT** and **ERR** LED's on the front panel will flash for a second and the sign-on message will appear on the terminal. Following the message, the prompt 'OK>' will be displayed. This indicates that the SR530 is ready to accept commands.

Type the letter 'P' followed by a carriage return (P<cr>). The SR530 responds by sending to the terminal the characters 0.00 indicating that the phase is set to 0 degrees. In general, a command with no arguments or parameters reads a setting of the unit. To set the phase to 45 degrees, type the command, P45<cr>. To see that the phase did change, use the **SELECT** key on the front panel to display the phase on the **REFERENCE**

DIGITAL DISPLAY. Typing the phase read command, P<cr>, will now return the string 45.00 to the terminal.

Now read the gain using the sensitivity read command, G<cr>. The response should be 24 meaning that the sensitivity is at the 24th setting or 500 mV. Change the sensitivity by typing G19<cr>. The sensitivity should now be 10 mV. Check the front panel to make sure this is so.

The Channel 1 Output of the lock-in is read by typing the command, Q1<cr>. The response is a signed floating point number with up to 5 significant digits plus a signed exponent. Change the gain to 10 uV using the G10 command. The response to the Q1 command will now be similar to the previous one except that the exponent is different.

Attach a DC voltmeter to the **X6** output on the rear panel. The range should allow for 10V readings. The voltage at the **X6** output can be set using the X6 command. Type **X6**,5.0<cr> and the X6 output will change to 5.0V. To read this back to the terminal, just type **X6**<cr>. When setting the **X6** voltage, the voltage may be sent as an integer (5), real (5.000), or floating point (0.500E1) number. Now connect the **X6** output to the **X1** input (also on the rear panel). **X1** through **X4** are analog input ports. To read the voltage on **X1**, simply type **X1**<cr>. The response 5.000 should appear on the terminal. The analog ports **X1** through **X6** can be used by your computer to read outputs of other instruments as well as to control other laboratory parameters.

At this point, the user should experiment with a few of the commands. A detailed command list follows.

SR530 Command List

The leading letters in each command sequence specify the command. The rest of the sequence consists of parameters. Multiple parameters are separated by a comma. Those parameters shown in {} are optional while those without {} are required. The variables m and n represent integers while v represents a real number. Parameters m and n must be expressed in integer format while v may be in integer, real, or floating point format.

AX
AY
AR
AP
The **A** command causes the **auto offset (rel)** function to execute. Auto offset is performed by reading the output and using that value as the appropriate offset. Every time an "AX" command is received, the auto offset function is executed on the X output. The "AY" command auto offsets the Y output. The "AR" command auto offsets the R output. Note that "AX" and "AY" will affect the R output but "AR" will not affect X and Y. The "AP" command will execute the auto-phase routine. This is done by setting the reference phase shift with the present phase difference between the signal and the reference input. The ‾ output then reads zero and the reference display reads the signal phase shift. "AP" maximizes X and minimizes Y but R is unaffected. The A commands may be issued at any time, regardless of the DISPLAY setting.

B {n}
If n is "1", the B command sets the **bandpass** filter in. If n is "0", the bandpass filter is taken out. If n is absent, then the bandpass filter status is returned.

C {n}
If n is "1", the C command sets the **reference LCD display** to show the phase setting. If n is "0", the LCD will display the reference frequency. If n is absent, the parameter being displayed (frequency or phase) is returned. Note that the P and F commands are used to read the actual values of the phase and frequency.

D {n}
If n is included, the D command sets the **dynamic reserve**. If n is absent, the dynamic reserve setting is returned.

n	Dyn Res
0	LOW
1	NORM
2	HIGH

Note that not all dynamic reserve settings are allowed at every sensitivity.

E m {,n}
The E command sets and reads the status of the output **expands**. If m is "1", then Channel 1 is selected, if m is "2", Channel 2 is selected. The parameter m is required. If n is "1", the E command expands the selected output channel. If n is "0", the expand is turned off for the selected channel. If n is absent, the expand status of the selected channel is returned. Note that the expands do not affect the X and Y BNC outputs, only the Channel 1 and 2 outputs.

F
The F command reads the reference **frequency**. For example, if the reference frequency is 100 Hz, the F command returns the string "100.0". If the reference frequency is 100.0 kHz, the string "100.0E+3" is returned. The F command is a read only command.

G {n}
If n is included, the G command sets the **gain** (sensitivity). If n is absent, the gain setting is returned.

n	Sensitivity
1	10 nV
2	20 nV
3	50 nV
4	100 nV
5	200 nV
6	500 nV
7	1 μV
8	2 μV
9	5 μV
10	10 μV
11	20 μV
12	50 μV
13	100 μV
14	200 μV
15	500 μV
16	1 mV
17	2 mV
18	5 mV
19	10 mV
20	20 mV
21	50 mV
22	100 mV

23 200 mV
24 500 mV

Note that sensitivity settings below 100 nV are allowed only when a pre-amplifier is connected.

H
The H command reads the **pre-amplifier status**. If a pre-amplifier is connected, a "1" is returned, otherwise, a "0" is returned. The H command is a read only command.

I {n}
If n is included, the I command sets the **remote-local** status. If n is absent, the remote-local status is returned.

    n   Status

    0   Local: all front panel keys are operative

    1   Remote: front panel keys are not
        operative. The **LOCAL** key returns the
        status to local.

    2   Lock-out: front panel keys are not
        operative. No key returns the status to
        local. Another I command is needed to
        return to local.

When using the GPIB interface, the REN, LLO, and GTL commands are not implemented. The I command is used by both interfaces to set the remote-local status.

J {n1,n2,n3,n4}
The J command sets the RS232 **end-of-record** characters sent by the SR530 to those specified by the decimal ASCII codes n1-n4. If no argument is included, the end-of-record sequence returns to the default (a carriage return), otherwise, up to four characters may be specified. The end-of-record required by the SR530 when receiving commands is not affected.

K n
The K command simulates a front panel **key press**. The effect is exactly the same as pressing the selected key once. The parameter n is required.

    n   Key
    1   Post Time Constant Up
    2   Post Time Constant Down
    3   Pre Time Constant Up
    4   Pre Time Constant Down
    5   Select Display (f/phase)

    6   90° Up
    7   90° Down
    8   Zero Phase (Simultaneous 90° Up and
        Down)
    9   Reference Trigger Mode
    10 Reference Mode (f/2f)
    11 Degrees Up
    12 Degrees Down
    13 Channel 2 Rel
    14 Channel 2 Offset (On/Off)
    15 Channel 2 Offset Up
    16 Channel 2 Offset Down
    17 Channel 2 Expand
    18 Output Display Up
    19 Output Display Down
    20 Channel 1 Expand
    21 Channel 1 Rel
    22 Channel 1 Offset (On/Off)
    23 Channel 1 Offset Up
    24 Channel 1 Offset Down
    25 Dyn Res Up
    26 Dyn Res Down
    27 Sensitivity Up
    28 Sensitivity Down
    29 Local
    30 Line X 2 Notch Filter
    31 Line Notch Filter
    32 Bandpass Filter

L m {,n}
The L command sets and reads the status of the line **notch filters**. If m is "1", then the 1X line notch is selected, if m is "2", the 2X line notch is selected. The parameter m is required. If n is "1", the L command sets the selected filter in. If n is "0", the selected filter is taken out. If n is absent, the status of the selected filter is returned.

M {n}
If n is "1", the M command sets the **reference mode** to 2f. If n is "0", the reference mode is set to f. If n is absent, the reference mode is returned.

N {m}
If m is "1", the N command sets the ENBW to 10 Hz. If m is "0", the **ENBW** is set to 1 Hz. If m is absent, the ENBW setting is returned.

OX {n} {,v}
OY {n} {,v}
OR {n} {,v}
The "OX", "OY", and "OR" commands set the **offsets** for the X, Y, and R outputs respectively. If n is "1", the offset is turned on. If n is "0", the offset is turned off. If n and v are absent, the offset status (on or off) is returned. (The value of the offset is read using the S and Q commands.)

If n is included, then v may be sent also. v is the offset value up to plus or minus full scale in units of volts. For example, to offset half of full scale on the 100 μV sensitivity, v should be "50.0E-6" or an equivalent value. However, if the sensitivity is then changed to 200 μV, the offset is now half of the new full scale or 100 μV. When the sensitivity is changed, the offset is preserved as a constant fraction of full scale rather than as a voltage referred to the input. The expand function will, on the other hand, preserve the value of the offset as an input referred voltage. Once a value of v is sent, the offsets may be turned off and on without losing the offset values by using the O commands without the v parameter. Note that the X and Y offsets will affect the R output but the R offset does not affect the X or Y output.

P {v}

If v is absent, the P command returns the **reference phase shift** setting from -180 to +180 degrees. When v is included, the phase is set to the value of v up to ±999 degrees.

Q1
Q2
QX
QY

The Q commands return the **output** values in units of volts or degrees. For an input signal of 50 μV on a full scale sensitivity of 100 μV, a Q command will return the string "50.00E-6". "Q1" and "Q2" read the parameters being shown on the Channel 1 and Channel 2 output displays as selected with the S command. "QX" and "QY" read the X (RCOS Ø) and Y (RSIN Ø) BNC outputs.

R {n}

If n is included, the R command sets the **reference input trigger** mode. If n is absent, the trigger mode is returned.

n	Mode
0	ositive
1	Symmetric
2	Negative

S {n}

If n is included, the S command selects the parameters shown on the Channel 1 and 2 analog meters, output digital displays, and output BNC's. If n is absent, the displayed parameter is returned.

n	Channel 1	Channel 2
0	X	Y
1	X Offset	Y Offset
2	R	Ø
3	R Offset	Ø
4	X Noise	Y Noise
5	X5 (D/A)	X6 (D/A)

T m {,n}

The T command sets and reads the status of the **time constants**. If m is "1", the pre time constant is selected, if m is "2", the post time constant is selected. The parameter m is required. If n is included, the T command sets the selected time constant. If n is absent, the setting of the selected time constant is returned.

n	Pre Time Constant (m=1)	
1	1	mS
2	3	mS
3	10	mS
4	30	mS
5	100	mS
6	300	mS
7	1	S
8	3	S
9	10	S
10	30	S
11	100	S

n	Post Time Constant (m=2)	
0	none	
1	0.1	S
2	1	S

U m {,n}

The U command sets and reads the unit's **calibration** bytes. m is the address offset of the byte, 0-511. If n is absent, the value of the addressed calibration byte is returned. If n is included, the addressed calibration byte is set to the value of n, 0-255. The new value will be in effect until the power is turned off or a reset command is issued. Use of this command is not recommended.

V {n}

If n is included, the V command sets the GPIB **SRQ** (service request) mask to the value n (0-255). If n is absent, the value of the SRQ mask is returned.

W {n}

The W command sets and reads the RS232 character wait interval. If n is included, the SR530 will **wait** nx4 mS between characters sent over the RS232 interface. This allows slow computer interfaces to keep up. n can range from 0 to 255. If n is absent, the wait value is returned. The wait interval is set to 6 on power-up.

X n {,v}

n designates one of the 6 general purpose **analog ports** located on the rear panel. If n is 1,2,3, or 4, the X command will return the voltage on the designated analog input port (X1-X4) in volts. If n is 5 or 6, then v may also be sent. If v is included, the designated analog output port (X5 or X6) will be set to v volts where v has the range -10.238V to +10.238V. If v is absent, the output value of the selected port is returned. On power-up, port X5 is the ratio output. An "X 5" command will read the ratio output. An "X 5" command with the parameter v will set port X5 to v volts, overriding the ratio output. Port X5 will return to the ratio output on power-up or reset.

Y {n}

The Y command reads the **status** byte. (See the following section for a definition of the Status Byte.) n designates one bit, 0-7, of the status byte. If n is included, the designated bit of the status byte is returned. The bit which is read is then reset. If n is absent, the value of the entire byte is returned and all status bits are then reset. This status byte may also be read over the GPIB using the serial poll command.

Z

The Z command causes an internal **reset**. All settings return to the default values shown on page 15. The **ERR** LED will be on for about three seconds to indicate that the stored instrument settings are being ignored. If the RS232 echo mode is on, the sign-on message is sent over the RS232 interface.

Status Byte

The SR530 maintains an 8-bit status register which the user may read to obtain information on the unit's status. The status byte may be read in two ways: by sending the Y command, which returns the value of the byte in ASCII coded decimal, or, when using the GPIB, by performing a serial poll. The returned status byte reflects all of the status conditions which have occurred since the last time the byte was read. After the status byte has been read, it is cleared. Thus, the status byte should be read initially to clear all previous conditions (especially after a power up or after settings have been changed).

The definitions for each bit of the status byte are given below:

Bit 0
Not Used

Bit 1
Command Parameter Out of Range. This bit is set if a parameter associated with a command is not in the allowed range.

Bit 2
No Reference. This bit is set when no reference input is detected, either because the amplitude is too low or the frequency is out of range.

Bit 3
Unlock. This bit is set when the reference oscillator is not locked to the reference input. If there is no reference input, bit 2 (no reference) will be set but bit 3 (unlock) may not be.

Bit 4
Overload. This bit is set if there is a signal overload. This can happen when the sensitivity is too high, the dynamic reserve is too low, the offset is on, or the expand is on. Overloads on the general purpose A/D inputs or the ratio output are not detected.

Bit 5
Auto Offset Out of Range. This bit is set if the auto offset function cannot zero the output because the output exceeded 1.024X full scale.

Bit 6
SRQ. This bit is set if the SR530 has generated an SRQ on the GPIB interface. This bit is reset after the SR530 has been serial polled. This bit is set only for status reads via a serial poll, ie., Bit 6 always zero for the RS232 .

Bit 7
Command Error. This bit is set when an illegal command string is received.

Errors

Whenever a 'parameter out of range' or an 'unrecognized command' error occurs, the appropriate status bits are set and the ERR LED flashes. In addition, any commands remaining on the current command line (up to the next <cr>) are lost. The **ERR** LED will also light if any of the internal communication buffers overflows. This occurs when 240 characters are pending on the command queue or output queue. The **ERR** LED will go off as soon as all buffers drop below 200

characters again.

Reset

The Z command resets the unit to its default state. The default front panel settings are listed in the **DEFAULTS** section of the **Guide to Operations**. In addition, the interface status returns to LOCAL, the SRQ mask is cleared, the RS232 character WAIT interval is set to 6, and the terminating sequence is reset to the proper defaults.

The command and output buffers are cleared by the Z command. Therefore, it is bad practice to use the Z command before all previous commands have been processed and all responses have been received.

Trouble-Shooting Interface Problems

If you are having difficulty getting your computer to communicate with the SR530 look to the sections on the RS232 and GPIB interfaces for some tips specific to your particular interface.

An ASCII terminal is a valuable aid for debugging interface problems. You can use it to:

1)   become familiar with the SR530's command structure,

2)   see GPIB bus transactions by using the GPIB echo mode,

3)   eavesdrop on transactions when using the RS232 interface,

4)   substitute a human for the SR530 by using a null modem cable (to make the DTE a DCE) and attaching the terminal to the port to which you would normally have connected the SR530. This allows you to test your program's responses to inputs which you provide from the terminal.

Common Hardware Problems include:

1)   The RS232 or GPIB cables are not properly attached.

2)   The configuration switches for the RS232 characteristics or GPIB address are not set correctly (Make sure the RS232 echo is off when using the RS232 interface with a computer. The GPIB with RS232 echo mode should be off when not debugging the GPIB interface.)

3)   Your computer requires an RS232 control line to be asserted, but your cable does not pass it between the SR530 and the computer, or, your computer is not asserting the DTR line on the RS232.

Common Software Problems include:

1)   You have sent the wrong command to ask for data from the SR530. Your program will wait forever for a response which is not going to come. This may not be your fault; we have seen Microsoft's Interpreted Basic on the IBM PC occasionally send a curly bracket (ASCII 253) when it was supposed to have sent a carriage return (ASCII 13).

2)   Your computer's baud rate has been changed and no longer matches the SR530's baud rate.

3)   The initial command sent to the SR530 was invalid due to a garbage character left in the command queue from power-up, or, the first character in you computer's UART is garbage, also due to power-up. It is good practice to send a few carriage returns to the SR530 when your program begins, and have your program clear-out its UART at the start of your program.

4)   The SR530 is not sending the correct 'end-of- record' marker for your computer. For example, it appears that Microsoft's Rev 3.2 FORTRAN on the IBM PC under DOS 2.1 requires two carriage returns for an end-of-record marker. The J command can be used to set the SR530 end-of-record marker to 2 carriage returns. [The end-of-record marker is that sequence which indicates that the response is complete. From the keyboard, a single carriage return is the end-of-record marker.]

5)   Answers are coming back from the SR530 too fast, overwriting the end-of-record markers, and causing the computer to hang waiting for a complete response. In this case, the W command can be used to slow down the response time of the SR530 preventing overwriting.

6) Answers are coming back from the SR530 too slowly due to the W6 default setting for the character interval time. Use the W command to speed up the transmission from the SR530. This can cause problems for the GPIB interface if the echo mode is on (switch 6 of SW1).

The SR530 with the RS232 Interface

The RS232 is a popular serial interface standard for bit serial communication. Despite the existence of the standard there are many permutations of control lines, baud rates, and data formats. If you do not have a lot of experience interfacing RS232 equipment you should read Appendix B for a description of the RS232 and interfacing tips.

Data Communications Equipment (DCE)

The SR530 is configured as DCE so that it may be connected directly to a terminal. If the SR530 is to be interfaced with another DCE device, a special cable (sometimes referred to as a 'modem' cable) is required. To use the RS232 interface you must set the switches in SW2 to match your computer's baud rate, parity, and number of stop bits. Refer to Page 7 for details.

Wait Command

The SR530 normally waits until the RS232 'Clear to Send' control line (CTS) is asserted before sending characters. However, some computers do not set and reset the CTS line, possibly causing the SR530 to send data when the computer is not ready to read it. The SR530 may be 'slowed down' using the W command. Sending 'Wn' causes the unit to wait nx4 mS before sending each character over the RS232 bus. The command W0 sets the wait interval to zero and results in the fastest transmission. The wait interval is set to 6 (24 mS)on power-up.

Termination Sequences

The default RS232 termination characters are sufficient to interface with most computers, however, it will occasionally be necessary to send special terminating sequences to fit the requirements of some computers. This can be done with the J command. The format for the command is:

    J {n1,n2,n3,n4}

where n1, n2, n3, and n4 are decimal values between 0 and 255 corresponding to the ASCII codes of the desired termination characters. For instance, if the desired termination sequence is an asterisk, (ASCII 42), two carriage returns, (ASCII 13), and a line-feed, (ASCII 10), the appropriate command is:

    J 42,13,13,10

If a G command is sent requiring an answer of 24 (sensitivity = 500 mV), the SR530 would respond with the string

    24*<cr><cr><lf>

Up to four terminating characters may be specified by the J command. If no arguments are sent with the J command, the terminating sequence returns to the default (echo on: <cr><lf>; echo off: <cr>).

The J command does not affect the terminating character (<cr>) required at the end of commands received by the SR530. It also does not affect the terminating sequence sent with data over the GPIB interface.

The SR530 with the GPIB Interface

For a brief introduction to the GPIB standard, please read Appendix C at the back of this manual. Before using the GPIB interface you must set the switches in SW1 per the instructions on page 7.

GPIB Capabilities

The GPIB capabilities of the SR530 consistent with IEEE standard 488 (1978) are shown in the table below. Also shown are the responses of the SR530 to some standard commands.

Code	Function
SH1	Source handshake capability
AH1	Acceptor handshake capability
T5	Basic Talker, Serial Poll, Unaddressed to talk if addressed to listen
L4	Basic Listener, Unaddressed to listen if addressed to talk
SR1	Service request capability
PP0	No parallel poll capability

26

DC1 Device Clear capability
RL0 REN,LLO, GTL not implemented.
   'I' command sets Remote-Local.

SR530 Response to GPIB Commands

Mnemonic	Command	Response
DCL	Device Clear	Same as Z command
SDC	Selected Device Clear	Same as Z command
SPE	Serial Poll Enable	Send Status Byte, & clear status byte

Because the SR530 can be controlled by an RS232 interface as well as the GPIB, the remote-local functions are not standard. There is no local with lock out state. When in the local state, remote commands are processed, even without the REN command being issued. This is because the RS232 interface has no provision for bus commands and remote commands over the RS232 interface would never be enabled.

Serial Polls and Service Requests

The status byte sent by the SR530 when it is serial polled is the same status byte which is read using the Y command (except for bit 6, SRQ). Ofcourse, when the SR530 is serial polled, it does not encode the status byte as a decimal number. The SR530 can be programmed to generate a service request (SRQ) to the GPIB controller every time a given status condition occurs. This is done using the V{n} command. The mask byte, n (0-255), is the SRQ mask byte. The mask byte is always logically ANDED with the status byte. If the result is non-zero, the SR530 generates an SRQ and leaves the status byte unchanged until the controller performs a serial poll to determine the cause of the service request. When the unit has been serial polled, the status byte is reset to reflect all of the status conditions which have occurred since the SRQ was generated.

For example, if we want to generate an SRQ whenever there is an overload or unlock condition, we need an SRQ mask byte equal to 00011000 binary, or 24 decimal ("V24" command). The byte 00011000 binary corresponds to the status byte with the 'no reference' and 'unlock' status bits set. If an overload occurs, then an SRQ will be generated. The serial poll will return a status byte showing SRQ and overload. If an unlock condition occurs before the serial poll is concluded, another SRQ will be generated as soon as the serial poll is finished. A second serial poll will reflect the unlock condition.

Any SRQ generated by the 'no reference, 'unlock', 'overload', and 'auto over-range' conditions will also reset the corresponding bit in the SRQ mask byte. This is to prevent a constant error condition (such as no reference applied to the input) from continually interrupting the controller. When such an SRQ occurs, the controller should change some parameter so as to solve the problem, and then re-enable the SRQ mask bit again using the V command.

GPIB with RS232 Echo Mode

It is sometimes useful when debugging a GPIB system to have some way of monitoring exactly what is going back and forth over the bus. The SR530 has the capability to echo all characters sent and received over the GPIB to its RS232 port. This mode of operation is enabled by setting switch 6 of **SW1** to the DOWN position. The baud rate, stop bits, and parity of the RS232 port are still set by **SW2**. Of course, the RS232 port operates at much lower speeds than the GPIB and will slow down the GPIB data rate in this mode. (Use the W0 command to allow the RS232 interface to run at full speed, otherwise, the GPIB transactions may take so long that the controller can hang.) During actual use, this mode should be disabled.

The SR530 with BOTH Interfaces

If both interfaces are connected, commands may be received from either interface. Responses are always sent to the source of the request (except in GPIB echo mode). It is unwise to send commands from the two interfaces at the same time since the characters from different sources can become interleaved on the command queue and result in 'unrecognized command' errors.

The Lock-in Technique

The Lock-in technique is used to detect and measure very small ac signals. A Lock-in amplifier can make accurate measurements of small signals even when the signals are obscured by noise sources which may be a thousand times larger. Essentially, a lock-in is a filter with an arbitrarily narrow bandwidth which is tuned to the frequency of the signal. Such a filter will reject most unwanted noise to allow the signal to be measured. A typical lock-in application may require a center frequency of 10 KHz and a bandwidth of 0.01 Hz. This 'filter' has a Q of 10^6 - well beyond the capabilities of passive electronic filters.

In addition to filtering, a lock-in also provides gain. For example, a 10 nanovolt signal can be amplified to produce a 10 V output--a gain of one billion.

All lock-in measurements share a few basic principles. The technique requires that the experiment be excited at a fixed frequency in a relatively quiet part of the noise spectrum. The lock-in then detects the response from the experiment in a very narrow bandwidth at the excitation frequency.

Applications include low level light detection, Hall probe and strain gauge measurement, micro-ohm meters, C-V testing in semiconductor research, electron spin and nuclear magnetic resonance studies, as well as a host of other situations which require the detection of small ac signals.

A Measurement Example

Suppose we wish to measure the resistance of a material, and we have the restriction that we must not dissipate very much power in the sample. If the resistance is about 0.1Ω and the current is restricted to 1 μA, then we would expect a 100 nV signal from the resistor. There are many noise signals which would obscure this small signal -- 60Hz noise could easily be 1000 times larger, and dc potentials from dissimilar metal junctions could be larger still.

In the block diagram shown below we use a 1Vrms sine wave generator at a frequency w_r as our reference source. This source is current limited by the 1 $M\Omega$ resistor to provide a 1 μA ac excitation to our 0.1Ω sample.

Two signals are provided to the lock-in. The 1VAC reference is used to tell the lock-in the exact frequency of the signal of interest. The lock-in's Phase-Lock Loop (PLL) circuits will track this input signal frequency without any adjustment by the user. The PLL has two outputs, $\cos(w_r t)$ and $\sin(w_r t)$.

The signal, $Vs \cos(w_s t+\varnothing)$, from the sample under test is amplified by a high gain ac coupled differential amplifier. The output of this amplifier is multiplied by the PLL outputs in two Phase-Sensitive Detectors (PSD1 and PSD2). This multiplication shifts each frequency component of the input signal, w_s, by the reference frequency, w_r, so that the output of the PSD's are given by:
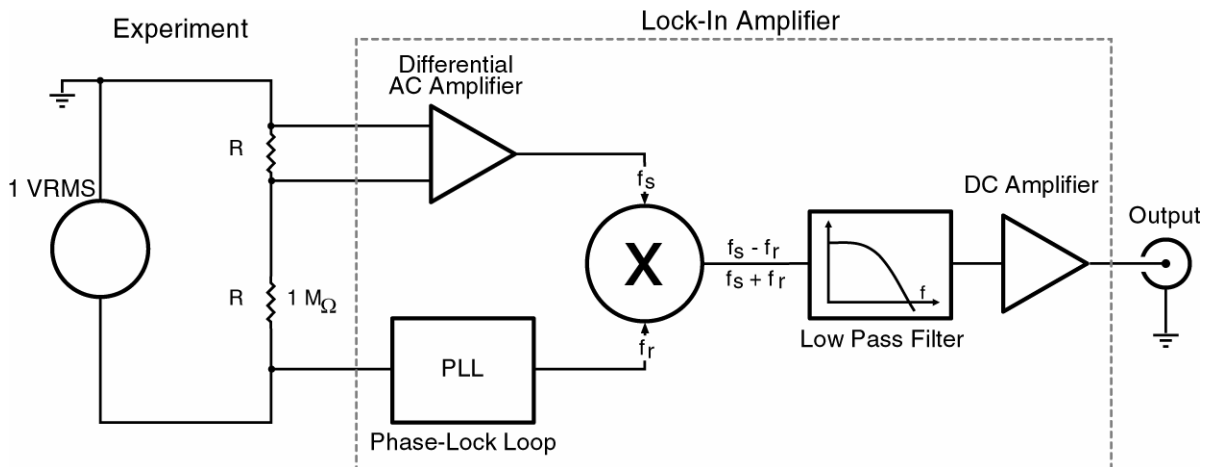
$$V_{psd1} = V_S \cos(w_r t) \cos(w_S t + \emptyset)$$
$$= 1/2\, V_S \cos[(w_r + w_S)t + \emptyset] +$$
$$1/2\, V_S \cos[(w_r - w_S)t + \emptyset]$$

$$V_{psd2} = V_S \sin(w_r t) \cos(w_S t + \emptyset)$$
$$= 1/2\, V_S \sin[(w_r + w_S)t + \emptyset] +$$
$$1/2\, V_S \sin[(w_r - w_S)t + \emptyset]$$

The sum frequency component of each PSD is attenuated by a low pass filter, and only those difference frequency components within the low pass filter's narrow bandwidth will pass through to the dc amplifiers. Since the low pass filter can have time constants up to 100 seconds, the lock-in can reject noise which is more than .0025 Hz away from the reference frequency input.

For signals which are in phase with the reference ($\bar{}=0_i$), the output of PSD1 will be a maximum and the output of PSD2 will be zero. If the phase is non-zero, Vpsd1 ~ $\cos(\emptyset)$ and Vpsd2 ~ $\sin(°)$. The magnitude output is given by,

$$R = \{(V_{psd1})^2 + (V_{psd2})^2\}^{1/2} \sim V_S$$

and is independent of the phase $\emptyset$. The phase output is defined as

$$\emptyset = -\tan^{-1}(V_{psd2}/ V_{psd1})$$

Thus, a dual-phase lock-in can measure the amplitude of the signal, independent of the phase, as well as measure an unknown phase shift between the signal and the reference.

Understanding the Specifications

The table below lists some specifications for the SR530 lock-in amplifier. Also listed are the error contributions due to each of these items. The specifications will allow a measurement with a 2% accuracy to be made in one minute.

We have chosen a reference frequency of 5 kHz so as to be in a relatively quiet part of the noise spectrum. This frequency is high enough to avoid low frequency '1/f' noise as well as line noise. The frequency is low enough to avoid phase shifts and amplitude errors due to the RC time constant of the source impedance and the cable capacitance.

The full-scale sensitivity of 100 nV matches the expected signal from our sample. The sensitivity is calibrated to 1%. The instrument's output stability also affects the measurement accuracy. For the required dynamic reserve, the output stability is 0.1%/°C. For a 10°C temperature change we can expect a 1% error.

A front-end noise of 7 nV/√Hz will manifest itself as a 1.2 nVrms noise after a 10 second low-pass filter since the equivalent noise bandwidth of a single pole filter is 1/4RC. The output will converge exponentially to the final value with a 10-second time constant. If we wait 50 seconds, the output will have come to within 0.7% of its final value.

The dynamic reserve of 60 dB is required by our expectation that the noise will be a thousand times larger than the signal. Additional dynamic reserve is available by using the bandpass and notch filters.

A phase-shift error of the PLL tracking circuits will cause a measurement error equal to the cosine of the phase shift error. The SR530's 1° phase accuracy will not make a significant contribution to the measurement error.

Specifications for the Example Measurement

Specification	Value	Error
Full Scale Sensitivity	100 nV	
Dynamic Reserve	60 dB	
Reference Frequency	5 kHz	
Gain Accuracy	1%	1%
Output Stability	0.1%/°C	1%
Front-End Noise	< 7 nV/√Hz	1.2%
Output Time Constant	> 10 S	0.7%
Total RMS Error		2%

Shielding and Ground Loops

In order to achieve the 2% accuracy given in this measurement example, we will have to be careful to minimize the various noise sources which can be found in the laboratory. (See Appendix A for a brief discussion on noise sources and shielding) While intrinsic noise (Johnson noise, 1/f noise and alike) is not a problem in this measurement, other noise sources could be a problem. These noise sources can be reduced by proper shielding. There are two methods for connecting the lock-in to the experiment: the first method is more convenient, but the second eliminates spurious pick-up more effectively.

In the first method, the lock-in uses the A input in a 'quasi-differential' mode. Here, the lock-in detects the signal as the voltage between the center and outer conductors of the A input. The lock-in does not force A's shield to ground, rather it is connected to the lock-in's ground via a 10Ω resistor. Because the lock-in must sense the shield voltage (in order to avoid the large ground loop noise between the experiment and the lock-in) any noise pickup on the shield will appear as noise to the lock-in. For a low impedance source (as is the case here) the noise picked up by the shield will also appear on the center conductor. This is good, because the lock-in's 100 dB CMRR will reject most of this common mode noise. However, not all of the noise can be rejected, especially the high frequency noise, and so the lock-in may overload on the high sensitivity ranges.
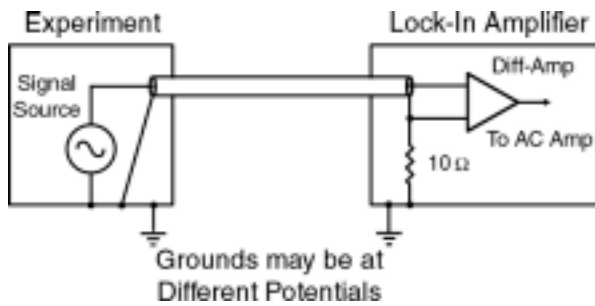
Quasi-Differential Connection

The second method of connecting the experiment to the lock-in is called the 'true-differential' mode. Here, the lock-in uses the difference between the center conductors of the A & B inputs as the input signal. Both of the signal sources are shielded from spurious pick-up.
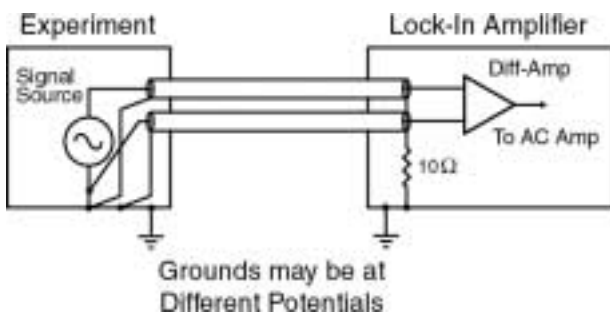
True-Differential Connection

With either method, it is important to minimize both the common mode noise and the common mode signal. Notice that the signal source is held near ground potential in both cases. A signal which appears on both the A & B inputs will not be perfectly cancelled: the common mode rejection ratio (CMRR) specifies the degree of cancellation. For low frequencies the CMRR of 100 dB indicates that the common mode signal is canceled to 1 part in 10^5, but the CMRR decreases by about 6 dB/octave (20 dB/Decade) starting at 1KHz. Even with a CMRR of 10^5, a 10 mV common mode signal behaves like 100nV differential signal.

There are some additional considerations in deciding how to operate the lock-in amplifier:

Dynamic Reserve (DR) is the ratio of the largest noise signal that the lock-in can tolerate before overload to the full-scale input. Dynamic reserve is usually expressed in dB. Thus a DR of 60 dB means that a noise source 1000 times larger than a full scale input can be present at the input without affecting the measurement of the signal. A higher DR results in a degraded output stability since most of the gain is DC gain after the phase sensitive detector. In general, the lowest DR which does not cause an overload should be used.

The Current Input has a 1 kΩ input impedance and a current gain of 10^6 Volts/Amp. Currents from 500 nA down to 100 fA full scale can be measured. The impedance of the signal source is the most important factor to consider in deciding between voltage and current measurements. For high source impedances, (>1 MΩ), and small currents use the current input. Its relatively low impedance greatly reduces the amplitude and phase errors caused by the cable capacitance-source impedance time constant. The cable capacitance should still be kept small to minimize the high frequency noise gain of the current preamplifier.

For moderate source impedances, or larger currents, the voltage input is preferred. A small value resistor may be used to shunt the source. The lock-in then measures the voltage across this resistor. Select the resistor value to keep the source bias voltage small while providing enough signal for the lock-in to measure.

The Auto-Tracking Bandpass Filter has a Q of 5 and follows the reference frequency. The passband is therefore 1/5 of the reference frequency. The bandpass filter can provide an additional 20 dB of dynamic reserve for noise signals at frequencies outside the passband. The filter also improves the harmonic rejection of the lock-in. The second harmonic is attenuated an additional 13dB and higher harmonics are

attenuated by 6 dB/octave more. You may wish to use the bandpass filter and select a low dynamic reserve setting in order to achieve a better output stability. Since the processor can only set the bandpass filter's center frequency to within 1% of the reference frequency, this filter can contribute up to 5° of phase shift error and up to 5% of amplitude error when it is used. In addition, the bandpass filter adds a few nanovolts of noise to the front end of the instrument when it is in use.

Line Notch Filters should be used in most measurement situations. The filters will reject about 50 dB of line frequency noise (about a factor of 300). If your reference frequency is one octave away, then these filters will introduce a 5° phase shift error, and a few percent amplitude error. Their effect on your signal is negligible if your reference frequency is more than two octaves away.

The frequency range of the SR530 lock-in amplifier extends from 0.5Hz to 100KHz. No additional cards are required for the instrument to cover its full frequency range. The SR530 can be used to detect a signal at the reference frequency or at twice the reference frequency to allow for convenient measurement of the harmonic of the signal.

Output Filters can have one pole (6 dB per octave) or two poles (12 dB/octave). A two-pole filter provides a signal to noise improvement over a single-pole filter due to its steeper roll off and reduced noise bandwidth. Single-pole filters are preferred when the lock-in is used in a servo system to avoid oscillation.

In many servo applications, no output filtering is needed. In this case, the SR530 may be modified to reduce the output time constant to about 20 μS. Contact the factory for details.

Noise measurement is a feature which allows direct measurement of the noise density of the signal at the reference frequency. This is a useful feature to assess at what frequency you should run your experiment.

Ratio Capability allows the lock-in's output to be divided by an external voltage input. This feature is important in servo applications to maintain a constant loop gain, and in experiments to normalize a signal to the excitation level.

Computer Interface allows a computer to control and to record data from the instrument. This is the single most important feature for extending the lock-in's capabilities and it's useful lifetime. Measurements which are impractical without a computer become simple when a computer is used to coordinate various parts of the experiment.

The Internal Oscillator provides a reference source for the lock-in. This allows the lock-in's frequency to be set without an additional signal generator. It also provides a sine wave to be used as the signal stimulus in an experiment. The frequency may be set via the computer interface as well as manually.

LOCK-IN AMPLIFIER DIAGRAM
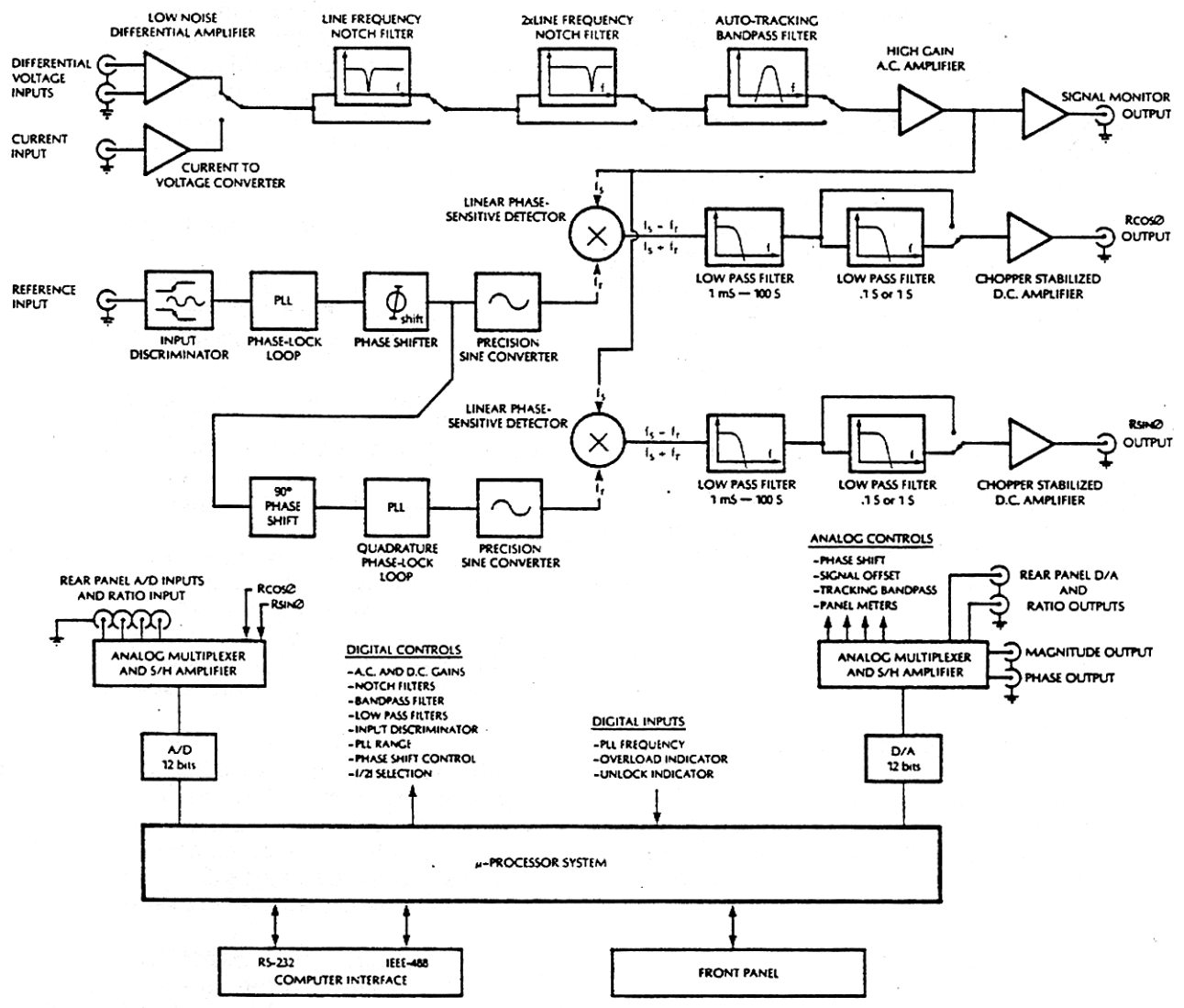
SR530 Block Diagram

Several new concepts are used to simplify the design of SR530 lock-in amplifier. In addition to implementing recent advances in linear integrated circuit technology, the instrument was designed to take full advantage of its microprocessor controller to improve performance and to reduce cost.

As an example of the new techniques used in the SR530, consider the harmonic rejection problem. Previously, lock-in amplifiers used a PLL with a square wave output. The Fourier components of the square wave created a serious problem -- the lock-in would respond to signal and noise at f, 3f, 5f,.ad infinitum. Quite often, one component of

this picket fence of frequencies would land on some noise source, giving a spurious result. To overcome this difficulty designers employed tuned amplifiers or heterodyning techniques. All of these 'fix-ups' had drawbacks, including phase and amplitude errors, susceptibility to drift, and card-swapping to change frequencies.

In contrast, the SR530 detects the signal by mixing a reference sine wave in a precision analog multiplier. Because of the low harmonic content of this sine wave, the instrument is insensitive to harmonics. This approach has eliminated the difficulty, performance compromises, and cost of the older techniques.

32

The Signal Channel

The instrument has both current and voltage inputs. The current input is a virtual ground, and the 100 MΩ voltage inputs can be used as single-ended or true differential inputs.

There are three signal filters. Each of these filters may be switched 'in' or 'out' by the user. The first filter is a line notch filter. Set to either 50 or 60 Hz, this filter provides 50 dB of rejection at the line frequency. The second filter provides 50 dB of rejection at the first harmonic of the line frequency. The third filter is an auto-tracking bandpass filter with a center frequency tuned by the micro-processor to the frequency of the signal. These three filters eliminate most of the noise from the signal input before the signal is amplified.

A high-gain ac amplifier is used to amplify the signal before entering the phase sensitive detector. The high gain which is available from this programmable amplifier allows the lock-in to operate with a lower gain in its dc amplifier. This arrangement allows high stability operation even when used on the most sensitive ranges.

Reference Channel

The processor controlled reference input discriminator can lock the instrument's PLL to a variety of reference signals. The PLL can lock to sine waves or to logic pulses with virtually no phase error. The PLL outputs are phase shifted and shaped to provide two precision sine waves. The two sine waves have 90° of phase shift between them.

Phase Sensitive Detectors

The Phase Sensitive Detectors are linear multipliers which mix the amplified and filtered signal with the reference sine waves. The difference frequency component of the multipliers' outputs are dc signals that are proportional to the amplitude of the signal. The low-pass filters which follow each multiplier can reject any frequency components which are more than a fraction of a Hertz away from the signal frequency.

DC Amplifiers and System Gain

Dc amplifiers amplify and offset the outputs of the two low pass filters. The total system gain is the product of the ac and dc amplifier gains. The partitioning of the system gain between these ac and dc amplifiers will affect the stability and dynamic reserve of the instrument. The output is most stable when most of the gain is in the ac amplifier, however, high ac gain reduces the dynamic reserve.

For the most demanding applications, the user may specify how the system gain is partitioned. However, with prefilters that are able to provide up to 100 dB of dynamic reserve, and with chopper stabilized dc amplifiers, most users will not be concerned with just how the system gain is allocated.

A Microprocessor Based Design

The instrument was designed to take full advantage of its microprocessor controller. This approach provides several key advantages...

The instrument may be interfaced to a laboratory computer over the RS232 and IEEE-488 interfaces. In addition to simply reading data from the lock-in, the computer can control all of the instrument settings with simple ASCII commands.

A key feature of the instrument is its four A/D inputs and two D/A outputs. These analog I/O ports may be used to read and supply analog voltages to an experiment or measurement. All of the input and output ports have a full-scale range of ±10.24VDC with 2.5 mV resolution and 0.05% accuracy.

Computer control can eliminate set-up errors, reduce tedium, allow more complete data recording and post measurement analysis. Also, the computer can play an active role in the data acquisition by adjusting gains, etc., in response to changing measurement conditions.

The microprocessor based design eliminates many analog components to improve performance, reliability, and reduce cost. For example, the magnitude and phase outputs are calculated by the microprocessor instead of using an analog vector summer. This eliminates the temperature drifts and inaccuracies associated with nonlinear analog circuits and greatly reduces the number of parts. Each unit is computer calibrated at the factory, and calibration constants are placed in the instrument's read-only memory. The SR530 has only one-fifth of the analog trimming components that are found in older designs.

Circuit Description

Introduction

The SR530 Lock-in amplifier is an integrated instrument combining state of the art analog design with advanced microprocessor based control and interfaces. This discussion is intended to aid the advanced user in gaining a better understanding of the instrument.

The SR530 has eight main circuit areas: the signal amplifier, the reference oscillator, the demodulator, the analog output and controls, the front panel, the microprocessor, the computer interfaces, and the power supplies. With the exception of the front panel, the quadrature oscillator and demodulator, and a few pieces of hardware, the entire lock-in is built on a single printed circuit board. Each section is isolated from the others as much as possible to prevent spurious signal pickup. To aid in the location of individual components, the first digit (or first two digits of a four digit part number) of each part number generally refers to the schematic sheet number on which it occurs. To help find the part on the circuit board, the parts list includes a location on the circuit board for each component. Parts with a four-digit part number beginning with 10,11, or 12 are found on the quadrature detector plug-in board located in the center of the main circuit board. Part numbers beginning with 6 refer to parts on the front panel.

Signal Amplifier

Assuming the input selector switch is set to a voltage input, the signal is coupled in through capacitors C101 and C102. The input impedance is set by the 100 MΩ resistors R101 and R102 over the operating frequency range. Note that R103 isolates the signal shields from the instrument ground forcing the return signal current back along the cable shields. The signal is then applied differentially to the gates of Q101. Q101 is a low noise dual JFET. The drain current through R109 is kept constant by 2/2 U101. The other half of U101 maintains a virtual null between the drains of the two transistors and thus an identical current flows through R110. Any input that would cause a differential between the two drains is amplified by 1/2 U101 and fed back via R112 in such a way as to reduce that differential. Since the two transistors are at equal and constant currents, their gate-source potentials are constant. Thus, the fed back signal which appears at the source of the right hand transistor exactly matches the input . Likewise, this signal will match the input

to the left hand transistor but with the opposite sign. Resistors R112 and R110 attenuate the fed back signal from the output of U101 resulting in a differential input, single ended output, fixed gain of 10 amplifier. P101 adjusts the current balance between the two transistors and therefore their gain match and common mode rejection.

The output of the pre-amp is scaled by resistors R119-R122 and analog switch U103 which make up a 1-2-5-10 attenuator. The signal is then amplified by 2/2 U102. Input overload is sensed through diodes D101-D104.

Current Amplifier

When the input selector is set to current, the input to the pre-amp comes from the output of the current to voltage converter, 1/2 U102. U102 is a low voltage-noise bipolar op amp. Q102 serves as an input buffer to provide low current-noise to the input. The op amp always maintains a null at the gates of Q102 thus providing an input impedance of 1KΩ (R128). The input current is converted to a voltage by R135 and the op amp. Q103 bootstraps out the summing junction capacitance of Q102.

Notch Filters

U107 is a high Q, line frequency, notch filter which can be switched in and out by analog switch 1/4 U106. The frequency and depth of the filter can be adjusted with P102 and P103. Resistors R146-R149 and switch U108 make up a selectable attenuator. U118 is a line frequency 2nd harmonic notch filter selected by 2/4 U106. P104 and P105 adjust the frequency and depth. The second notch filter has a gain of 3 and its output is scaled by U110 and resistors R156-R159. The signal then takes two paths; to inverting amplifier U111 and to the input of the tracking bandpass filter. U111 has the same gain as the bandpass filter. The output of either U111 or the bandpass filter is selected by 3/4 U112 and 4/4 U106 and amplified by U113. U114 and U115 provide a last stage of gain and scaling and the final output is ac coupled and buffered by 4/4 U208.

Bandpass Filter

The bandpass filter is a three op amp state-variable active filter. 3/4 of U201 make up the three op amps of the standard filter. U203,

U204, and U205 are analog switches which select the feedback capacitors for the 5 decades of operation. The two halves of U202 are matched transconductance amplifiers operating as programmable, voltage controlled, current sources which take the place of the normal, frequency setting, resistors. A voltage proportional to the reference frequency is converted into a current by 1/4 U208 and Q201. This current programs the effective "resistance" of the two transconductance amplifiers and thus, tunes the center frequency of the filter to follow the reference. The output of the filter is buffered by 4/4 U201. The two remaining op amps in U208 are used to detect signal overloads throughout the amplifier chain.

Reference Oscillator

The reference input signal is ac coupled and buffered by U301. R378 isolates the reference shield from the lock-in ground to prevent ground loop currents. 1/2 U303 switches the polarity of the reference reaching comparator U304. U305 is a retriggerable one-shot whose output indicates a no reference condition if no comparator pulses are generated for three seconds.

U309 is a dual transconductance amplifier in a triangle VCO configuration. U310 selects the integrating capacitor depending on the frequency range. The VCO frequency is determined by the programming current through R318 and therefore by the output voltage of U308. C306 is the phase-locked loop low pass filter which is buffered by U308. U307 is a programmable current source used to charge and discharge C306. The amount of current available to U307 is determined by the VCO control voltage, thus, the tracking rate of the VCO is proportional to the VCO frequency. The triangle output is compared to a constant voltage by U314. 1/2 U313 and 1/2 U312 select f or 2f operation. This signal is fed back to the phase detector U306 to be compared with the reference output of U304. U315 compares the triangle output with a variable voltage to generate a square-wave signal phase-shifted from the reference. The range of this fine phase shift control is -5 to 95 degrees.

The output of U315 serves as the reference to a second phase-locked loop. This second PLL uses a similar proportional tracking triangle VCO. Comparator U329 looks at the square wave output of the VCO while comparator U328 detects the zero crossings of the triangle output. 1/2 U327 selects one these comparators to feed back to the phase detector, U316. Since the square and triangle outputs are in quadrature, U327 selects either an in-

phase or quadrature relationship between the two VCO's. Thus, the output of the second VCO can be shifted from -5 to 185 deg from the reference.

The triangle output is divided by R363 and R362 before reaching transconductance amplifier 2/2 U322. The amplitude of the triangle input to this amplifier is enough to just saturate the input and provide a sine wave output. 2/2 U325 then amplifies the sine wave before it goes to the demodulator. U324 is a comparator which generates a square wave in-phase with the sine output. U326 divides the frequency of the square wave by eight and 2/2 U327 selects the frequency of the square wave chopper.

The square wave output of U322 serves as the reference to the quadrature oscillator PLL. This PLL is identical to the triangle oscillator, sine wave shaper described above. U1004 detects the zero-crossings of the triangle wave to feed back to the phase comparator, U1002. This ensures that the quadrature triangle wave is 90 deg out of phase from the first sine wave. The quadrature triangle is shaped into a sine wave by 2/2 U1009 and amplified by 2/2 U1014. U1012 is a comparator which generates a square wave in-phase with the quadrature sine wave. U1013 divides the frequency of the square wave by eight and 1/2 U1011 selects the frequency of the square wave chopper.

Demodulator and Low Pass Amplifier

Amplifier U402 and switch U401 select the polarity of the reference sine wave. This allows phase shifts up to 360 degrees from the reference input. The sine wave is ac coupled by U403 and inverted by U404. U405 selects alternating polarities of the sine wave at the chopper frequency, f/2 or f/16. This chopped sine wave is then multiplied by the output of the signal amplifiers by the analog multiplier U406. The synchronous output of the multiplier that corresponds to the in-phase signal is a square wave at the chopper frequency. The output is ac coupled by U407 to remove the dc offset of the multiplier. U408 inverts the signal and U405 chops the square wave to recover a dc output. U409 buffers the chopper output before the first low pass time constant. Op amps U416 and 2/2 U402 make up the first low pass amplifier with relays U411-U415 and U417 selecting the time constant. The second low pass amplifier is

U419. Analog switch U418 selects the time constant and gain. The full scale output of U418 is 5 volts.

The quadrature demodulator and low pass amplifiers are identical to that described above. The quadrature detector output is provided by U1119.

Analog Output and Control

The dc output of the demodulator/low pass amplifiers is passed to the reference input of multiplying DAC U502. The DAC is programmed with the appropriate attenuation to calibrate the overall gain of the lock-in. Every gain setting in each dynamic reserve is calibrated independently and the proper attenuations are stored in the unit's ROM.

The quadrature output is calibrated by DAC U1201. Amplifiers U1204 and U1205 buffer the two demodulator outputs to drive the X and Y BNC's.

A/D's

Analog multiplexer U504 selects the signal to be digitized by the microprocessor. This signal can be either the lock-in's in-phase or quadrature output or one of the four independent analog inputs buffered by U501. These general purpose inputs are located on the rear panel of the instrument. The selected signal is sampled and held on capacitor C502 and buffered by 4/4 U508. The A/D conversion is done by successive approximation using comparator U514 to compare the sampled and held signal with known outputs of U505, a 12 bit DAC with a precision reference. Note that the output of U506, an 8 bit DAC is summed with the output of U505. This 8 bit DAC corrects for offset errors which can accumulate as analog voltages pass through buffers, S/H amps, and comparators. These offsets are measured after each unit is manufactured, and values to compensate for these offsets are placed in the unit's ROM. The polarity of the offset-corrected 12 bit DAC is set by 2/4 U511 and the SIGN bit yielding 13 bits of resolution from -10.24 to +10.24 volts.

D/A's

In addition to providing reference voltages for A/D conversion, the DAC output voltage may be multiplexed by U507 to one of eight sample and hold amplifiers which provide analog output and control voltages. The microprocessor refreshes each S/H amplifier every few milliseconds to prevent droop. Two of these outputs are available as general programmable outputs on the rear panel. Two are used to program the band pass filter and the reference oscillator phase shift. One output is subtracted from the lock-in output in U508 to provide a variable offset and another is the rms noise output. The remaining two outputs generate the magnitude and phase output voltages.

Expand

3/4 U511 and 4/4 U1202 are the expand amplifiers. They provide a selectable gain of 10 to the channel 1 and 2 outputs just before the output buffers.

Front Panel

There are 71 led's on the front panel controlled by 9 serial-in, parallel-out shift registers. 8 of the shift registers are written to simultaneously and the 9th is written separately. 8 consecutive write operations are required to set the LED's in each case. The liquid crystal displays are managed by the display controllers, U6101, U6102, and U6103. Exclusive-or gates U6104, U6105 and U6106 drive the left over segments. Latches U6107 and U6108 provide the logic bits for these extra segments as well as the keyboard row strobes. U6109 reads the switch closures as the rows are scanned.

Microprocessor Control

The microprocessor, U701, is a Z80A CPU clocked at 4 MHz. 16K bytes of firmware are stored in the ROM, U702. U703 is a 2K byte static RAM, backed-up by a lithium battery. A power-down standby circuit, Q701, preserves the RAM contents when the power is turned off. The battery has a life of 5-10 years. The CPU has power-up and power-down resets to prevent erroneous execution during turn-on or short sags in the line voltage.

U704 is a 3-channel counter. One channel generates the baud rate for the RS232 interface while the other two are used to measure the frequency or period of the reference oscillator. U709 provides a gate pulse to counter 0. Multiplexer U708 selects whether the gate is a single period of the reference (period measurement) or a gate of known duration (frequency measurement). Counter 1 is a programmable divide by N counter whose output is either counted for one period of the reference,

or, generates the gate pulse during which reference pulses are counted.

I/O addresses are decoded by U705, U706, and U707. The microprocessor controls the lock-in functions through I/O ports U714-U721. U713 generates an interrupt to the CPU every 4 msec to keep the microprocessor executing in real time.

RS232 Interface

The RS232 interface uses an 8251A UART, U801, to send and receive bytes in a bit serial fashion. Any standard baud rate from 300 to 19.2K baud may be selected with the configuration switches. The X16 transmit and receive clock comes from counter 2 of U704. The RS232 interface is configured as DCE so that a terminal may be connected with a standard cable. When a data byte is received by the UART, the RxRDY output interrupts the CPU to prevent the data from being overwritten.

GPIB Interface

The interface to the GPIB is provided by U802, an MC68488 General Purpose Interface Adapter (GPIA). The GPIB data and control lines are buffered by drivers U808 and U811. Because the GPIA uses a 1 MHz clock, wait states are provided by U805 to synchronize I/O transactions with the 4 MHz CPU. The GPIA interrupts the CPU whenever a GPIB transaction occurs which requires the CPU's response. (The GPIB address is set by switch bank SW1.)

Power Supplies

The line transformer provides two outputs, 40VAC and 15VAC, both center tapped. The transformer has dual primaries which may be selected by the voltage selector card in the fuse holder. The 15VAC is rectified by diode bridge BR2 and passed to 5V regulator U909. The output of U909 powers the microprocessor and its related circuitry. The 40VAC output is half-wave rectified by BR1 and regulated by U901 and U902 to provide +20V and -20V. These two dc voltages are then regulated again by 15V regulators U903-U908. Each 15V regulator powers a separate section of the lock-in to reduce coherent pick up between sections. U911 and U912 provide plus and minus 7.5V and U910 generates +5V for the analog circuits.

Internal Oscillator

The internal oscillator is on a small circuit board attached to the rear panel of the instrument. Local regulators, Q1 and Q2, provide power to the board. The VCO input is internally pulled up by R12. This pulls the VCO input to 10V when the VCO input is left open. 2/4 U1 translates the VCO input voltage to provide a negative control voltage to U2, the function generator. P3 adjusts the VCO calibration. U2 is a sine wave generator whose frequency range is selected by the VCO Range switch and capacitors, C4-C6. P2 adjusts the sine wave symmetry at low frequencies. 4/4 U1 buffers the output of U2. P1 adjusts the amplitude of the output sine wave. The output amplitude on the SIne Out is selected by the amplitude switch. The output impedance is 600 Ω.

Calibration and Repair

This section details calibration of the instrument. Calibration should be done only by a qualified electronics technician.

********* **WARNING** *********

The calibration procedure requires adjusting the instrument with power applied and so there is a risk of personal injury or death by electric shock. Please be careful.

Most of the calibration parameters are determined by a computer aided calibration procedure after burn-in at the factory. These calibration parameters are quite stable and so will not need to be adjusted. Calibration parameters which may need field adjustment are detailed below.

Multiplier Adjustments

On the **HIGH** dynamic reserve setting, there can be some reference frequency feedthrough. This section describes how to null this unwanted output.

This adjustment requires an oscilloscope and a signal generator which can provide a 500Hz reference signal.

Allow the unit to warm up for about 1 hour.

Reset the unit by turning it off and back on while holding the **LOCAL** key down.

Select voltage input **A** and connect a 50 1/2 terminator or shorting plug to the **A** input BNC connector. Connect the 500 Hz reference signal to the reference input. Set the **SENSITIVITY** to **1mV** and the **DYN RES** to **HIGH**. The **PRE TIME CONSTANT** should be set to **1mS** and **the POST TIME CONSTANT** to **NONE**. Connect the scope to the **CHANNEL 1 OUTPUT** on the front panel. Set the scope to 2V/div and 5mS/div. Externally trigger the scope using the reference input signal.

After about 90 seconds, the scope display should show a 500 Hz sine wave on a 30 Hz (500/16 Hz) square wave. Remove the four screws holding the top panel on. Slide the top panel back about half way. Using a small screwdriver, adjust P402 at location D2 to

minimize the 500 Hz output. Adjust P403 at location C2 to minimize the 30 Hz output.

Now set the both time constants to **1S**. Adjust P404 at location F4 to zero the output. This adjustment has a range of 20% of full scale on the **HIGH** dynamic reserve setting. (2% on **NORM** and 0.2% on **LOW**). This zeroes the DC output of Channel 1 on all dynamic reserve ranges.

Now connect the scope to the **CHANNEL 2 OUTPUT**. Set the **PRE TIME CONSTANT** to **1mS** and the **POST TIME CONSTANT** to **NONE**. Adjust P1102 to minimize the 500 Hz output. Adjust P1103 to minimize the 30 Hz output. Set both time constants to **1S**. Adjust P1104 to zero the output. All three potentiometers are located on the plug-in board in the center of the main circuit board.

Replace the top panel.

Amplifier and Filter Adjustments

This section describes how to adjust the Common Mode Rejection and Line notch filter frequencies. An oscilloscope and a signal generator which can provide an accurate line frequency and twice line frequency sine wave are required.

Allow the unit to warm up for about 1 hour.

Reset the unit by turning it off and back on while holding the **LOCAL** key down.

Remove the four screws holding down the top panel. Slide the panel back about halfway.

CMRR

Set the reference frequency to 100 Hz. It is convenient to use the SYNC output of the signal generator as the reference input if it is available. Connect the sine output of the signal generator to the **A** input and set the input selector to **A**. With the **SENSITIVITY** at **100mV**, adjust the amplitude of the input signal to 100 mV (full scale).

Now set the input selector to **A-B** and connect the signal to both the **A** and **B** inputs. Set the **SENSITIVITY** to **20µV**, the **DYN RES** to **NORM** and the **BANDPASS** filter **IN**. Connect the scope to the **SIGNAL MONITOR** output on the rear panel. Set the scope to AC coupled, 0.2V/div, and 10mS/div. Externally trigger the scope using the reference input signal.

The CMRR is adjusted by the single turn potentiometer located at A1 under the single hole at the front of the signal shield. (The shield is the aluminum box on the left side of the main board). Using a small screwdriver, carefully adjust the potentiometer to minimize the 100 Hz output on the scope. Set the **DISPLAY** to **R,Ø** and the sensitivity to **5μV** and minimize the **R** output on the Channel 1 meter.

Notch Filters

Set the reference frequency to 60.0 Hz (50.0 Hz). It is convenient to use the SYNC output of the signal generator as the reference input if it is available. Connect the sine output of the signal generator to the **A** input and set the input selector to **A**. With the **SENSITIVITY** at **100mV**, adjust the amplitude of the input signal to 100 mV (full scale).

Set the **LINE NOTCH** to **IN**, the **SENSITIVITY** to **10mV**, and the **DYN RES** to **LOW**. Connect the scope to the **SIGNAL MONITOR** output on the rear panel. Set the scope to AC coupled, 0.2V/div, 10mS/div. Trigger the scope externally using the reference input signal.

The **LINE NOTCH** frequency and depth are adjusted by the pair of 20 turn potentiometers located under the middle two holes in the signal shield (row 4 on the circuit board). Using a small screwdriver, carefully adjust one pot until the line output on the scope is minimized. Then adjust the other pot until the output is minimized. Iterate between the two pots until there is no further improvement. Set the **SENSITIVITY** to **5mV**, **2mV**, and **1mV**, repeating the adjustments at each sensitivity.

Repeat this procedure using a reference frequency of 120.0 Hz (100.0 Hz) and the **LINEX2 NOTCH** filter. The **LINEX2 NOTCH** is adjusted by the pair of 20 turn potentiometers located under the back two holes in the signal shield (row 5 on the circuit board). Replace the top panel.

Replacing the Front-End Transistors

Both the voltage and current front end transistors (Q101 and Q102) are 2N6485 (IMF6485) dual JFETS. These transistors are selected at the factory to meet the noise specifications.

This section outlines their replacement procedure in the event that they become damaged during use.

1) **Remove the AC power cord from the unit.**

2) Remove top and bottom panels.

3) Release the signal shields by removing the four screws which hold it onto the circuit board. Be careful not to lose the nuts. Carefully slide the shields back and then lift them out.

4) The input transistors are located on the main board, just behind the input selector switch. Q101 is the voltage (**A, A-B**) front end, and Q102 is the current (I) front end. Desolder and replace the appropriate transistor.

5) Replace the signal shields. Be careful to check that the shields do not touch any circuit board traces around their edges.

6) Replace the top and bottom panels.

7) If Q101, the voltage front end has just been replaced, the Common Mode Rejection needs to be readjusted using the procedure described in the Amplifier Adjustments section.

Appendix A:
Noise Sources and Cures

Noise, random and uncorrelated fluctuations of electronic signals, finds its way into experiments in a variety of ways. Good laboratory practice can reduce noise sources to a manageable level, and the lock-in technique can be used to recover signals which may still be buried in noise.
Intrinsic Noise Sources

Johnson Noise. Arising from fluctuations of electron density in a resistor at finite temperature, these fluctuations give rise to a mean square noise voltage,

$$\overline{V^2} = \int 4kT\, Re[Z(f)]\, df = 4kTR\, \Delta f$$

where k=Boltzman's constant, $1.38 \times 10^{-23} J/°K$; T is the absolute temperature in Kelvin; the real part of the impedance, Re[z(f)] is the resistance R; and we are looking at the noise source with a detector, or ac voltmeter, with a bandwidth of Δf in Hz. For a 1MΩ resistor,

$$(\overline{V^2})^{1/2} = 0.13\ \mu V/\sqrt{Hz}$$

To obtain the rms noise voltage that you would see across this 1M½ resistor, we multiply $0.13\mu V/\sqrt{Hz}$ by the square root of the detector bandwidth. If, for example, we were looking at all frequencies between dc and 1 MHz, we would expect to see an rms Johnson noise of

$$(\overline{V^2})^{1/2} = 0.13\ \mu V/\sqrt{Hz} * (10^6\ Hz)^{1/2} = 130\ \mu V$$

'1/f Noise'. Arising from resistance fluctuations in a current carrying resistor, the mean squared noise voltage due to '1/f' noise is given by

$$\overline{V^2} = A\, R^2\, I^2\, \Delta f/f$$

where A is a dimensionless constant, 10^{-11} for carbon, R is the resistance, I the current, Δf the bandwidth of our detector, and f is the frequency to which the detector is tuned. For a carbon resistor carrying 10 mA with R = 1k, $\Delta f = f = 1Hz$, we have

$$V_{noise} = 3\ \mu Vrms$$

And Others. Other noise sources include flicker noise found in vacuum tubes, and generation and recombination noise found in semiconductors.

All of these noise sources are incoherent. Thus, the total noise is the square root of the sum of the squares of all the incoherent noise sources.

Non-Essential Noise Sources

In addition to the "intrinsic" noise sources listed above there are a variety of "non-essential" noise sources, i.e. those noise sources which can be minimized with good laboratory practice. It is worthwhile to look at what might be a typical noise spectrum encountered in the laboratory environment:
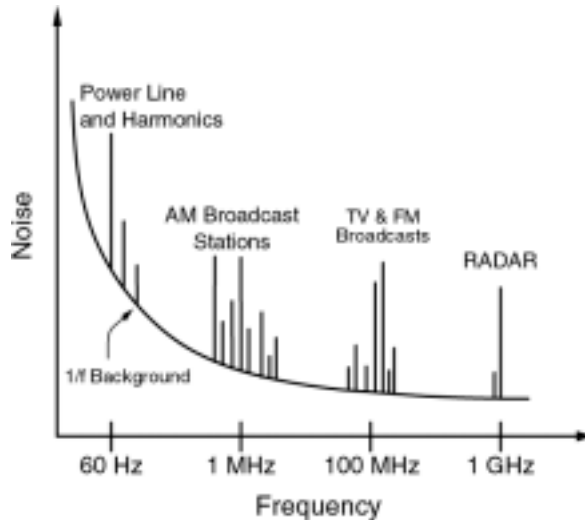
Noise Spectrum

Some of the non-essential noise sources appear in this spectrum as spikes on the intrinsic background. There are several ways which these noise sources work their way into an experiment.

Capacitive Coupling. A voltage on a nearby piece of apparatus (or operator) can couple to a detector via a stray capacitance. Although C_{stray} may be very small, the coupled in noise may still be larger than a weak experimental signal.
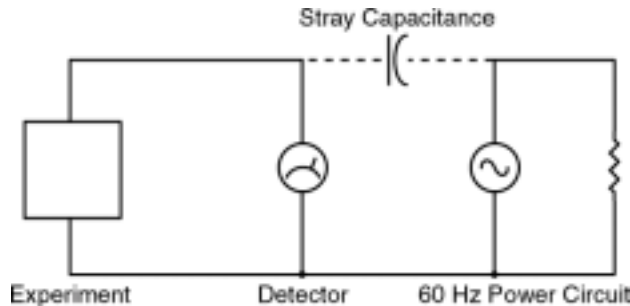
Stray Capacitance

Capacitive Noise Coupling

To estimate the noise current through C_{stray} into the detector we have

$$i = C_{stray} \frac{dV}{dt} = jwC_{stray}V_{noise}$$

where a reasonable approximation to C_{stray} can be made by treating it as parallel plate capacitor. Here, w is the radian frequency of the noise source (perhaps $2 * \pi * 60Hz$), V_{noise} is the noise voltage source amplitude (perhaps 120 VAC). For an area of $A = (.01 \text{ m})2$ and a distance of $d = 0.1m$, the 'capacitor' will have a value of 0.009 pF and the resulting noise current will be 400pA. This meager current is about 4000 times larger than the most sensitive current scale that is available on the SR510 lock-in.

Cures for capacitive coupling of noise signals include:

1) removing or turning off the interfering noise source,

2) measuring voltages with low impedance sources and measuring currents with high impedance sources to reduce the effect of i_{stray},

3) installing capacitive shielding by placing both the experiment and the detector in a metal box.

Inductive Coupling. Here noise couples to the experiment via a magnetic field:
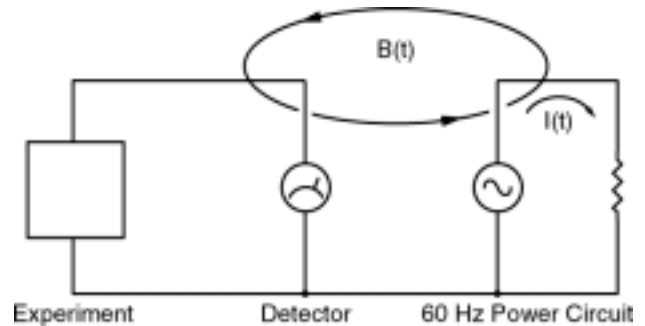
Inductive Noise Coupling

A changing current in a nearby circuit gives rise to a changing magnetic field which induces an emf in the loop connecting the detector to the experiment. (emf = $d\emptyset_B/dt$.) This is like a transformer, with the experiment-detector loop as the secondary winding.)

Cures for inductively coupled noise include:

1) removing or turning off the interfering noise source (difficult to do if the noise is a broadcast station),

2) reduce the area of the pick-up loop by using twisted pairs or coaxial cables, or even twisting the 2 coaxial cables used in differential hook-ups,

3) using magnetic shielding to prevent the magnetic field from inducing an emf (at high frequencies a simple metal enclosure is adequate),

4) measuring currents, not voltages, from high impedance experiments.

Resistive Coupling (or 'Ground Loops').
Currents through common connections can give rise to noise voltages.
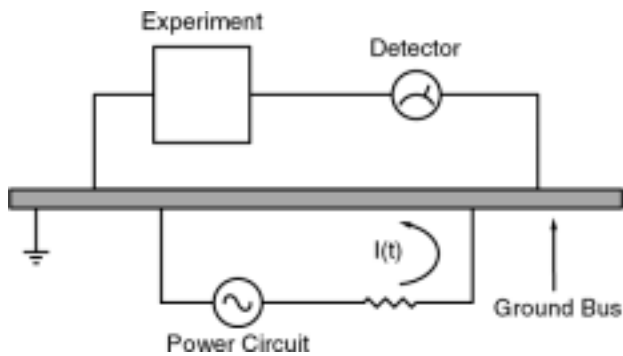
Resistive Coupling

Here, the detector is measuring the voltage across the experiment, plus the voltage due to the noise current passing through the finite resistance of the ground bus. This problem arises because we have used two different grounding points which are not at exactly the same potential. Some cures for ground loop problems include:

1) grounding everything to the same physical point,

2) using a heavier ground bus to reduce the potential drop along the ground bus,

3) removing sources of large currents from ground wires used for small signals.

Microphonics provides a path for mechanical noise to appear as electrical noise in a circuit or experiment. Consider the simple circuit below:
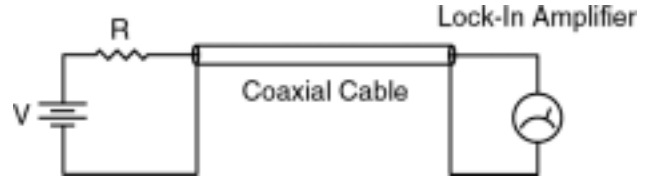
The capacitance of a coaxial cable is a function of its geometry so mechanical vibrations will cause the cable capacitance to vary with time. Since $C=Q/V$, we have

$$C \frac{dV}{dt} + V \frac{dC}{dt} = \frac{dQ}{dt} = i$$

so mechanical vibrations will cause a dC/dt which in turn gives rise to a current i, which will affect the detector. Ways to eliminate microphonic signals include:

1) eliminate mechanical vibrations,

2) tie down experimental cables so they will not sway to and fro,

3) use a low noise cable that is designed to reduce microphonic effects.

Thermocouple Effect. The emf created by dissimilar metal junctions can give rise to many microvolts of dc potential, and can be a source of ac noise if the temperature of the junction is not held constant. This effect is large on the scale of many low level measurements.

Appendix B:
Introduction to the RS232

The 'RS232' is a standard for bit serial asynchronous data communication. The standard defines the format for data transmission, the electrical specifications for the signal levels, and the mechanical dimensions of connectors.

Despite the definition of a standard, there are so many permutations of control lines, data formats, and transmission speeds, that getting two RS232 devices to communicate usually requires some work.

In this section, we will provide some basic information to aid you in connecting your RS232 device to the SR530 Computer Interface.

CASE 1 - The Simplest Configuration.
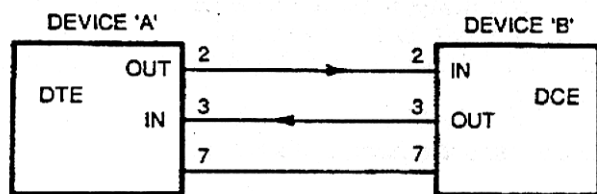
In this case, one wire is used to send data from device A to device B and another wire is used to send data from device B to device A. Notice that pin 2 is an output on device A and an input on device B. (It is good practice to run the ground, pin 7, between the devices as well). The RS232 defines two types of devices; DTE (Data Terminal Equipment) and DCE (Data Communications Equipment.) An RS232 port on a computer may be either a DTE or DCE but nearly every terminal with an RS232 port is a DTE. RS232 ports on a computer which are intended to connect to a modem, such as the COM1: port on the IBM PC, are DTE. The SR530 is configured as DCE, and so it may be directly connected to ASCII terminals and to the COM: ports on IBM PC's and compatibles.

As an example, consider connecting an RS232 ASCII computer terminal to the SR530 using a 2 wire link. The terminal is a DTE and the SR530 is a DCE. To operate correctly, the SR530 and the terminal must have the same settings for baud rate, parity, and number of stop bits. The control lines in the RS232 Standard, which are used to indicate that a device is ready to accept

data, must also be connected correctly at the terminal end. If the terminal responds to a control line, it will believe that the SR530 is not ready to accept data (because the line is not passed in this example) and will therefore not send any data.

CASE 2 - RS232 with Control Lines.
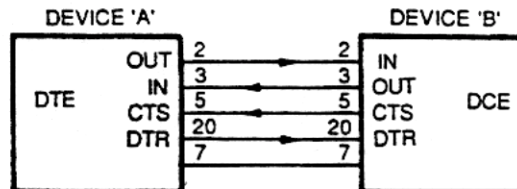
The data lines are the same as in Case 1. In addition to the data lines, there are two control lines used:

CTS - Pin 5
"Clear to send" is a signal asserted by the DCE to tell the DTE that the DCE is ready to receive data.

DTR - Pin 20
"Data Terminal Ready" is a signal asserted by the DTE to tell the DCE that the DTE is ready to receive data.

The SR530 responds to the control lines as follows:

1) If the lines are not connected, the SR530 assumes that you are ready to receive data.

2) Data will not be transmitted from the SR530 if the DTR line (pin 20) is low. This is useful in the case when your program is not yet ready to receive data. If data transmission is not suspended, then data may be overwritten in your computer's UART (as it is not being retrieved by the program and so will be lost.) When this happens, the 'over-run' flag will be set in your computer's UART and it may be recognized by the operating system, generating an error message such as "I/O Device Error" (See the "W" command in the SR530 Command List for another way to slow data transmission.)

Baud Rate

The RS232 baud rate of the SR530 is switch selectable from 300 to 19.2K baud (see configuration switch setting in the front of this manual.) 19.2K baud means that data is transmitted at 19,200 bits/second. With one start bit, 2 stop bits, 8 data bits, and no parity bits, each ASCII character requires 573 μsec to be transmitted (11bits/19.2K

baud.) The typical data string 5.1270<cr> has 7 characters, requiring 4 msec to be sent.

Stop Bits

Generally, selection of 2 stop bits will result in fewer data transmission errors.

Parity

The Parity bit provides a check against faulty data transfer. It is not commonly used in local data transmission environments. If the parity option is selected, the SR530 will transmit 8 data bits and a parity bit, however, no parity check of incoming data is done.

Voltage Levels

The RS232 uses bipolar voltage levels:
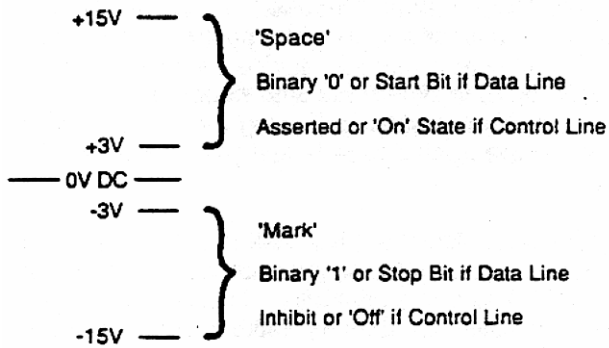
The control lines use positive logic. For example, the DCE tells the DTE that it is clear to send (CTS) by placing > +3 VDC on pin 5 of the interface. Similarly, the DTE can tell the DCE that it is not ready by placing -3 VDC on pin 20 (DTR) of the interface.

The data lines, pins 2 and 3, use negative logic. A 'zero' bit is represented by a positive voltage and a 'one' bit is represented by a negative voltage. A start bit is a positive voltage and a stop bit is a negative voltage. Data is transmitted with the least significant bit first. The
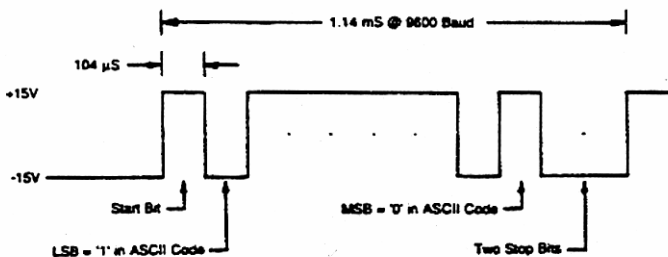
letter 'A', which has the ASCII code 41H (0100 0001), would appear as follows:
If a parity option was selected, the parity bit would be sent after the 8th data bit, but before the first stop bit.

Final Tip

When you are trying to get the RS232 to work with your computer, it is helpful to be able to 'eavesdrop' on the RS232 data lines going between the SR530 and the computer. This can be done with an ASCII RS232 terminal and the following connector:
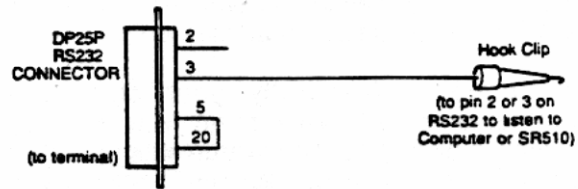
To test the connector, place the hook clip on pin 2 of the same connector (shorting pin 2 to pin 3.) Now, when you type at the terminal keyboard, data transmitted from pin 2 is received at pin 3 and displayed on the terminal screen. To use as a debugging tool, attach the hook clip to either pin 2 or pin 3 of the RS232 cable on the SR530 to show either data sent from the Computer or the SR530. The baud rate, parity, and stop bits of the terminal must match those of the SR530 and the computer. If your terminal has a mode which will display control characters (such as carriage returns and line feeds) it is helpful to operate in that mode.

A variant of the 'eavesdropping' approach is
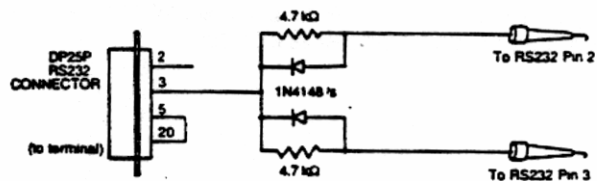
diagrammed below:

With this cable arrangement, the ASCII terminal can listen to the data passing in both directions. The only drawback is that the terminal will display garbled data if both devices transmit data at the same time.

44

Appendix C:
Introduction to the GPIB

The IEEE-488 Standard specifies the voltage levels, handshake requirements, timing, hardware details, pinout and connector dimensions for a 16 line, bit parallel bus. Many instruments may be connected in series to communicate over the same cable. Because the bits are passed in parallel, the GPIB is faster than the RS232.

The controller (generally your computer) coordinates data transfer on the bus by designating all participating instruments (including itself) as either a talker or a listener. Listeners can receive data placed on the bus by the Talker. Devices can have the capacity to operate in either mode. The address of each device is set by switches in the device and must be between 0 and 30.

Bus Description

Byte Transfer Control Group. This consists of 3 negative logic lines that implement the GPIB handshaking. The NRFD (Not Ready For Data) line is held low by any designated listener who is not ready to accept data. When every listener is ready, the line goes high and the talker may release data to the bus. After data is on the bus, the talker pulls the DAV (Data Valid) line down. At this point, each listener retrieves the data. Before and during the retrieval of the data, the listener holds the NDAC (No Data Accepted) line down. When every listener has received the data, the NDAC line goes high, allowing the talker to release the DAV line high. Finally, the listener pulls down the NDAC line until another transfer is initiated.

Data Bus: There are eight data lines which use negative logic and pass the bits of each byte in parallel.

General Interface Lines: These five lines operate independently of the handshake lines and use negative logic.

1) The EOI (End or Identify) line is used by the talker to designate the end of message.

2) The SRQ (Service Request) line is used by any device to ask for service. The controller can serial poll each device (each device returns an 8 bit status byte) to determine who needs attention. It can also do a parallel poll using the EOI and ATN lines where each device is assigned a single data line.

3) The ATN (Attention) line makes both talkers and listeners accept information and passes control of the DAV line to the controller. This line is used by the controller to identify talkers and listeners through their addresses.

4) The REN (Remote Enable) line changes the status of an instrument from local to remote.

5) The IFC (Interface Clear) line clears the bus of all data and activity.

Though GPIB is a very powerful interface, strict protocol must be observed for it to operate successfully.

Appendix D:
Program Examples

All of the program examples which follow do the same thing, only the computer, language, or interface is changed. The programs read the Channel 1 and 2 Outputs and write the results to the computer screen. In addition, the X6 analog output port is ramped from 0 to 10V.

Program Example 1:
IBM PC, Basic, via RS232

In this example, the IBM PC's ASYNC port (known as COM1: or AUX: to DOS users) will be used to communicate with the SR530. Only two wires between the IBM PC's ASYNC port and the SR530 are needed (pins #2 & #3 of the RS232), but pins 5,6,8 and 20 should be connected together on the connector at the IBM end.

```
10 '   EXAMPLE PROGRAM TO READ THE SR510 OUTPUT AND RAMP THE X6 ANALOG OUTPUT
20 '   USING IBM PC BASICA AND THE COM1: RS232 PORT.
30 '   THE RAMP ON X6 CAN BE WATCHED BY SETTING THE SR530 DISPLAY TO A/D.
40 '
50 '
60 '   ON THE REAR PANEL OF THE SR530, SET SWITCH #1 OF SW2 DOWN
70 '   AND ALL OTHER SWITCHES IN SW2 UP. (9600 BAUD, NO PARITY)
80 '
90 OPEN "COM1:9600,N,8,2,CS,DS,CD" AS #1
100 ' SET UP COM1: PORT TO 9600 BAUD, NO PARITY, 8 DATA BITS, 2 STOP BITS,
110 '              IGNORE CTS (CLEAR TO SEND), DSR (DATA SET READY),
120 '              AND CD (CARRIER DETECT).
130 '
140 PRINT #1, " " 'CLEAR UART BY SENDING SPACES
150 PRINT #1, "Z" 'RESET SR530
160 FOR I = 1 TO 200: NEXT I     'WAIT FOR RESET TO FINISH
170 '
180 X = 0            'INIT X6 OUTPUT TO ZERO
190 '
200 PRINT #1, "Q1"    'READ OUTPUT
210 INPUT #1,V1       'INTO V1
220 PRINT #1, "Q2"    'READ OUTPUT
230 INPUT #1,V2       'INTO V2
240 '
250 PRINT "CH1 = ";V1;"       CH2 = ";V2
260 '
270 X =X + .0025      'INCREMENT X6 OUTPUT BY 2.5 MV
280 IF X > 10 THEN X = 0   'RESET X6 RAMP
290 PRINT #1, USING "X6, ##.###";X  'SET X6 OUTPUT VOLTAGE
300 '
310 GOTO 200           'LOOP FOREVER
```

Program Example 2:
IBM PC, Microsoft Fortran
v3.3, via RS232

Machine language routines to interface to the COM1: RS232 port are provided in the file RS232.OBJ found on the SR575 disk. These routines allow for simple interfacing to the SR530 at 19.2 kbaud from FORTRAN programs.

To use these routines, the file 'for232.inc' (also on the SR575 disk) must be 'included' in the FORTRAN source.

Only two wires between the IBM PC's ASYNC port and the SR530 are needed (pins #2 & #3 of the RS232), but pins 5,6,8 and 20 should be connected together on the connector at the IBM end.

```
$storage:2
$include: 'for232.inc'
[     for 232.inc must be included to call subroutines in RS232.OBJ
[     link with RS232.OBJ (on SR565 disk)
[     RS232.OBJ defines:
[          init
[                     initializes COM1: to 19.2 kbaud
[          txstr (str) str is a string terminated with '$'
[                     transmits str to COM1:
[          rxstr (str) str must be declared with length of 15 or greater
[                     fills str with string received from COM1:
[          if and error occurs, nocom is called.
[          Nocom should be a FORTRAN subroutine in your program.

      program ex2

      character *20 str1,str2, str3

[     Example program to read the SR530 outputs and ramp the
[     X6 analog output using Microsoft FORTRAN v3.3 and the
[     COM1: port. Set all switches in SW2 to UP on SR530
[     for 19.2 kbaud.

[     The ramp on X6 can be watched by setting the SR530
[     display to D/A/

[     initialize COM1: port to 19.2 kbaud
      call init
[     set character wait interval to zero
      call txstr('w0$')

[     reset X6 to zero
      x6=0.0

[     read channel 1 output into string variable str1
20    call txstr('q1$')
      call rxstr(str1)
[     read channel 2 output into string variable str2
      call txstr('q2$')
```

```
      call rxstr(str2)

[     convert string variable into real variable v1 and v2
      read (str1,1000) v1
      read (str2,1000) v2
1000  format (bn,f10.0)


[     print results to screen
      write(*,2000) v1, v2
2000  format(' Channel 1=',G10.3,3x, 'Channel 2=',G10.3)

[     ramp x6 by 2.5 mV
      x6 = x6 + .0025
      if (x6.gt.10) x6 = 0.0

[     make x6 command string
      write (str3,3000) x6
3000  format ('x6,',f7.3,'$')
      call txstr(str3)

[     and loop forever
      goto 20

      stop
      end

[     *********************************
      subroutine nocom

[     in case of a timeout error, this routine runs
[     put your error handler here.

[     write(*,*) char (7)
      write(*,*)'RS232 Timeout Error! '

      stop
      end
```

Program Example 3:
IBM PC, Microsoft C v3.0,
via RS232

Machine language routines to interface to the COM1: RS232 port are provided in the file RS232.OBJ found on the SR575 disk. These routines allow for simple interfacing to the SR530 at 19.2 kbaud from C programs.

To use these routines, the large model must be used. Compile with the /AL switch and link with RS232.OBJ.

Only two wires between the IBM PC's ASYNC port and the SR530 are needed (pins #2 & #3 of the RS232), but pins 5,6,8 and 20 should be connected together on the connector at the IBM end.

```
#include <stdio.h>

/*      Compile with >MSC program name/AL;
        link with RS232.OBJ (on SR565 disk)
             RS232.OBJ defines:
             init ()
                                 Initializes COM1: to 19.2 kbaud
             txstr (str);
                   Char *str;  str must terminate with '$' char
                               Sends string str to COM1:
             rxstr (str);      str must be declared with 15 characters
                                 or more length.
                               Fills str with string received from COM1:

             If an error occurs, your procedure nocom() is called.
             Nocom() must be a C procedure in your program.

        Example program to read the SR510 outputs and ramp the x6 analog
        Output using Microsoft C v3.0 (large model) and the COM1: port.
        Set all switches in SW2 to UP on SR530 for 19.2 kbaud.

        The ramp on x6 can be watched by setting the SR530 display to D/A.

*/

main ()
        {
        char str1[20], str2[20], STR3[20];
        float v1,V2,x;

        init ();                /* init COM1: port to 19.2 kbaud */
        txstr ("w0$");          /* set character interval to 0 */

        x = 0;
        while (1)
                {
                txstr ("q1$");    /* read channel 1 output */
                rxstr (str1);     /* into str1 */
                sscanf (str1, "%f", &v1);  /* scan str1 for a float variable */
```

```
        txstr ("q2$");     /* read channel 2 output */
        rxstr (str2);       /* into str2 */
        sscanf (str2, "%f", &v2);  /* scan str2 for a float variable */

        x += 0.0025;          /* increment x6 output by 2.5 mV */
        if (x >= 10) x = 0;
        sprintf (str3, "X6,%f$", x);  /* make x6 command string */
        txstr (str3);                 /* send x6 command */

        /* print results to screen */
        printf ("Channel 1 = %10.36   Channel 2 = %10.36\n", v1, v2);
        }
    }
/* ****************************************** */
nocom ()
    /* error handling routine goes here */
    {
    printf("RS232 Timeout Error\n");
    putch (7);
    exit ();
    }
```

Program Example 4:
IBM PC,Microsoft Basic,
via GPIB

This program requires the Capital Equipment Corporation GPIB card for the IBM PC or XT. It has firmware in ROM to interface high level languages to the GPIB.

Subroutine calls in Microsoft BASIC are done to memory locations specified by the name of the subroutine. The address is relative to the segment address specified by the DEF SEG statement preceding CALL.

In this program, the CEC card's ROM starts at OC0000H, the system controller's address is 21, and the SR530 has been assigned as GPIB address 23.

To monitor the GPIB activity with an RS232 terminal, SW1-6 should be down, and the ASCII terminal should be attached to the rear panel RS232 connector.

```
10 '   EXAMPLE PROGRAM TO READ THE SR530 OUTPUT AND RAMP THE X6 ANALOG OUTPUT
20 '   USING IBM PC BASICA AND THE CAPITAL EQUIPMENT CORP. GPIB INTERFACE CARD
30 '
40 '   THE RAMP ON X6 CAN BE MATCHED BY SETTING THE SR530 DISPLAY TO D/A.
50 '
60 '   ON THE SR530 REAR PANEL, SET SWITCHES #4 AND #6 ON SW1 TO DOWN (DEVICE
70 '   ADDRESS = 23, RS232 ECHO ON) AND SWITCH # 1 ON SW2 TO DOWN (RS232 BAUD
80 '   RATE = 9600). ALL OTHER SWITCHES SHOULD BE UP.
90 '   NOTE THAT THE RS232 ECHO IS FOR DEBUGGING AND DEMOSTRATION PURPOSES,
100 ' UNDER NORMAL CONDITIONING, SWITCH # 6 OF SW1 SHOULD BE UP SINCE THE RS232
110 ' ECHO SLOWS DOWN THE GPIB INTERFACE.
120 '
130 DEF SEG = &HC000    'BASE ADDRESS OF CEC CARD
140 INIT=0: TRANSMIT=3: RECV=6:  'ADDRESSES OF CEC FIRM WARE ROUTINES
150 ADDR%=21: SYS%=0             'CONTROLLER ADDRESS
160 INZ$ = "IFC UNT UNL MTA LISTEN 23 DATA 'Z' 13"
170 '
180 Q1$ = "IFC MTA LISTEN 23 DATA 'Q1' 13"
190 Q2$ = "IFC MTA LISTEN 23 DATA 'Q2' 13"
200 X6$ = "IFC MTA LISTEN 23 DATA 'X6, "
210 LISN$ = "IFC UNT UNL MLA TALK 23"
220 '
230 '
240 CALL INIT(ADDR%,SYS%)        'INIT X6 OUTPUT TO ZERO
250 CALL TRANSMIT(INZ$,STATUS%)  'RESET SR530
260 GOSUB 600                    'CHECK TRANSMIT STATUS
270 '
280 X = 0   'INIT X6 OUTPUT TO ZERO
290 '
300 CALL TRANSMIT(Q1$,STATUS%)   'READ CHANNEL 1 OUTPUT
310 GOSUB 600
320 GOSUB 510                    'GET RESULT
330 V1 = VAL(ANS$)               'INTO V1
340 '
350 CALL TRANSMIT(Q2$,STATUS%)   'READ CHANNEL 2 OUTPUT
360 GOSUB 600
370 GOSUB 510                    'GET RESULT
380 V1 = VAL(ANS$)               'INTO V2
```

```
390 '
400 PRINT "CH1 = ";V1; "          CH2 =";V2
410 '
420 X = X + .0025        'INCREMENT X6 OUTPUT BY 2.5 MV
430 IF X>10 THEN X  0    'RESET RAMP
440 X$ = X6$ + STR$(X) + "' 13"  'MAKE X6 COMMAND STRING
450 CALL TRANSMIT (X$,STATUS%)   'SET NEW X6 VOLTAGE
460 GOSUB 600
470 '
480 GOTO 300       'LOOP FOREVER
490 '
500 ' GET AN ANSWER STRING FROM THE SR530
510 CALL TRANSMIT(LISN$,STATUS%) 'MAKE SR530 A TALKER
520 GOSUB 600
530 ANS$=SPACE$(10)              'INIT ANSWER STRING
540 CALL RECV(ANS$,LENGTH%STATUS%)  'READ RESULT INTO ANS$
550 GOSUB 600
560 RETURN
570 '
580 '
590 ' CHECK STATUS OF LAST TRANSMISSION FOR ERRORS
600 IF STATUS%=0 THEN RETURN       'STATUS OKAY
610 PRINT "STATUS CODE = ";STATUS%;" ON GPIB: ERROR"
620 STOP
```

Program Example 5:
HP85 via GPIB

This program provides an example of an HP85 program using the GPIB interface which could be used to control the lockin amplifier. In this example, the SR530 should be addressed as device #16 by setting the switch bank SW1 per the instructions Page 7.

```
10    x=0
20    OUTPUT 716 ; "Q"
30    ENTER 716 : V1
40    DISP "CH1 = " : V1
50    OUTPUT 716 ; "Q2"
60    ENTER 716 : V2
70    DISP "CH2 = " : V2
80    X = X + .0025
90    IF X>10 THEN X=0
100   OUTPUT 716 : "X6, ";X
110   GOTO 20
```

Documentation

This section contains the parts lists and schematics for the SR530 lock-in amplifier.

The first digit of any part number can be used to locate the schematic diagram for the part. For example, R415 is located on sheet 4 of the schematic diagrams.

SR530 COMPONENT PARTS LIST

Oscillator Board Parts List

REF.	SRS part#	VALUE	DESCRIPTION
C 1	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 2	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 3	5-00102-517	4.7U	Capacitor, Tantalum, 35V, 20%, Rad
C 4	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 5	5-00087-516	390P	Capacitor, Silver Mica, 500V, 5%, DM15
C 6	5-00102-517	4.7U	Capacitor, Tantalum, 35V, 20%, Rad
C 7	5-00014-501	390P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 8	5-00034-526	100U	Capacitor, Electrolytic, 35V, 20%, Rad
C 9	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 10	5-00034-526	100U	Capacitor, Electrolytic, 35V, 20%, Rad
C 11	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
P 1	4-00016-445	10K	Pot, Multi-Turn, Side Adjust
P 2	4-00003-440	100K	Trim Pot, Single Turn, In-Line Leads
P 3	4-00016-445	10K	Pot, Multi-Turn, Side Adjust
PC1	7-00037-701	SR501	Printed Circuit Board
R 1	4-00079-401	4.7K	Resistor, Carbon Film, 1/4W, 5%
R 2	4-00083-401	47K	Resistor, Carbon Film, 1/4W, 5%
R 3	4-00202-407	698	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 4	4-00189-407	41.2K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 5	4-00186-407	4.22K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 6	4-00190-407	42.2K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 7	4-00186-407	4.22K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 8	4-00202-407	698	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 9	4-00078-401	39K	Resistor, Carbon Film, 1/4W, 5%
R 10	4-00186-407	4.22K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 11	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 12	4-00042-401	15K	Resistor, Carbon Film, 1/4W, 5%
R 13	4-00070-401	30K	Resistor, Carbon Film, 1/4W, 5%
R 14	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 15	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 16	4-00079-401	4.7K	Resistor, Carbon Film, 1/4W, 5%
R 17	4-00104-401	82K	Resistor, Carbon Film, 1/4W, 5%
R 18	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 19	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 20	4-00188-407	4.99K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 21	4-00188-407	4.99K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 22	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 23	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 24	4-00031-401	100	Resistor, Carbon Film, 1/4W, 5%
R 25	4-00031-401	100	Resistor, Carbon Film, 1/4W, 5%
SW1	2-00013-215	DPDT	Switch, Toggle Right Angle PCB Mount
SW2	2-00013-215	DPDT	Switch, Toggle Right Angle PCB Mount
U 1	3-00087-340	LF347	Integrated Circuit (Thru-hole Pkg)
U 2	3-00085-340	ICL8038	Integrated Circuit (Thru-hole Pkg)
U 3	3-00118-325	78L15	Transistor, TO-92 Package
U 4	3-00124-325	79L15	Transistor, TO-92 Package
Z 0	0-00100-040	1/4X1/16	Washer, Flat
Z 0	0-00122-053	2-1/4" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00136-053	8-1/2" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin

SR530 COMPONENT PARTS LIST

Main Board Parts List

REF.	SRS part#	VALUE	DESCRIPTION
BR1	3-00062-340	KBP201G/BR-81D	Integrated Circuit (Thru-hole Pkg)
BR2	3-00062-340	KBP201G/BR-81D	Integrated Circuit (Thru-hole Pkg)
BT1	6-00001-612	BR-2/3A 2PIN PC	Battery
C 101	5-00069-513	.1U	Capacitor, Mylar/Poly, 50V, 5%, Rad
C 102	5-00069-513	.1U	Capacitor, Mylar/Poly, 50V, 5%, Rad
C 103	5-00038-509	10U	Capacitor, Electrolytic, 50V, 20%, Rad
C 104	5-00008-501	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 105	5-00002-501	100P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 106	5-00008-501	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 107	5-00030-520	2200U	Capacitor, Electrolytic, 16V, 20%, Rad
C 108	5-00030-520	2200U	Capacitor, Electrolytic, 16V, 20%, Rad
C 110	5-00038-509	10U	Capacitor, Electrolytic, 50V, 20%, Rad
C 111	5-00081-516	1P	Capacitor, Silver Mica, 500V, 5%, DM15
C 116	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 117	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 118	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 120	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 121	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 122	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 123	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 124	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 125	5-00030-520	2200U	Capacitor, Electrolytic, 16V, 20%, Rad
C 126	5-00030-520	2200U	Capacitor, Electrolytic, 16V, 20%, Rad
C 127	5-00057-512	.22U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 128	5-00057-512	.22U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 129	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 131	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 132	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 133	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 134	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 136	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 137	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 145	5-00009-501	24P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 146	5-00009-501	24P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 147	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 148	5-00017-501	47P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 201	5-00020-501	7.5P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 202	5-00109-525	150P	Capacitor, Polystyrene, 50V, 5%, Ax
C 203	5-00048-566	.0015U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 204	5-00051-512	.015U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 205	5-00055-512	.15U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 206	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 207	5-00059-512	.47U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 208	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 209	5-00109-525	150P	Capacitor, Polystyrene, 50V, 5%, Ax
C 210	5-00048-566	.0015U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 211	5-00051-512	.015U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 212	5-00055-512	.15U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 213	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
C 214	5-00059-512	.47U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 215	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 216	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 217	5-00038-509	10U	Capacitor, Electrolytic, 50V, 20%, Rad
C 218	5-00038-509	10U	Capacitor, Electrolytic, 50V, 20%, Rad
C 230	5-00055-512	.15U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 301	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 302	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 303	5-00009-501	24P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 304	5-00110-525	560P	Capacitor, Polystyrene, 50V, 5%, Ax
C 305	5-00038-509	10U	Capacitor, Electrolytic, 50V, 20%, Rad
C 306	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 307	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 308	5-00058-512	.33U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 310	5-00008-501	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 311	5-00008-501	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 312	5-00017-501	47P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 313	5-00017-501	47P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 314	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 315	5-00038-509	10U	Capacitor, Electrolytic, 50V, 20%, Rad
C 317	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 318	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 319	5-00058-512	.33U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 320	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 321	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 322	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 323	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 324	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 325	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 326	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 327	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 328	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 329	5-00033-520	47U	Capacitor, Electrolytic, 16V, 20%, Rad
C 330	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 331	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 332	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 333	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 334	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 335	5-00016-501	470P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 336	5-00016-501	470P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 337	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 338	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 401	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 402	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 403	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 404	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 405	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 406	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 407	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 408	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 409	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
C 410	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 411	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 412	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 413	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 414	5-00053-512	.033U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 415	5-00072-513	10U	Capacitor, Mylar/Poly, 50V, 5%, Rad
C 416	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 417	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 418	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 419	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 420	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 421	5-00013-501	33P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 422	5-00013-501	33P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 501	5-00012-501	330P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 502	5-00136-519	.01U	Capacitor, Polystyrene, 50V, 5%, Rad
C 503	5-00007-501	220P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 504	5-00002-501	100P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 505	5-00008-501	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 506	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 507	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 508	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 509	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 510	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 511	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 512	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 513	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 514	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 515	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 516	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 517	5-00002-501	100P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 518	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 519	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 520	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 521	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 523	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 525	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 526	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 527	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 701	5-00007-501	220P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 702	5-00007-501	220P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 703	5-00040-509	1.0U	Capacitor, Electrolytic, 50V, 20%, Rad
C 704	5-00040-509	1.0U	Capacitor, Electrolytic, 50V, 20%, Rad
C 705	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 706	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 707	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 708	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 709	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 710	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 711	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 712	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 801	5-00012-501	330P	Capacitor, Ceramic Disc, 50V, 10%, SL

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
C 802	5-00012-501	330P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 803	5-00012-501	330P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 804	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 805	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 806	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 807	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 808	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 809	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 901	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 902	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 903	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 904	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 905	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 906	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 907	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 908	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 909	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 910	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 911	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 912	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 913	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 914	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 915	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 916	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 917	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 918	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 919	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 920	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 923	5-00192-542	22U MIN	Cap, Mini Electrolytic, 50V, 20% Radial
C 924	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 925	5-00046-510	2200U	Capacitor, Electrolytic, 50V, 20%, Ax
C 926	5-00046-510	2200U	Capacitor, Electrolytic, 50V, 20%, Ax
C 927	5-00192-542	22U MIN	Cap, Mini Electrolytic, 50V, 20% Radial
C 928	5-00192-542	22U MIN	Cap, Mini Electrolytic, 50V, 20% Radial
C 929	5-00034-526	100U	Capacitor, Electrolytic, 35V, 20%, Rad
C 930	5-00034-526	100U	Capacitor, Electrolytic, 35V, 20%, Rad
C 931	5-00034-526	100U	Capacitor, Electrolytic, 35V, 20%, Rad
C 932	5-00034-526	100U	Capacitor, Electrolytic, 35V, 20%, Rad
C 933	5-00103-524	1.0U	Capacitor, Tantalum, 50V, 20%, Rad
C 934	5-00103-524	1.0U	Capacitor, Tantalum, 50V, 20%, Rad
C 935	5-00036-522	6800U	Cap, Electro. 25V 10% Ax, Mallory TCX
C 936	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 937	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 938	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 939	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
CN801	1-00014-160	9 PIN D	Connector, D-Sub, Right Angle PC, Female
CN802	1-00016-160	RS232 25 PIN D	Connector, D-Sub, Right Angle PC, Female
CN803	1-00238-161	GPIB SHIELDED	Connector, IEEE488, Reverse, R/A, Female
CX1	5-00010-501	270P	Capacitor, Ceramic Disc, 50V, 10%, SL
CX713	5-00014-501	390P	Capacitor, Ceramic Disc, 50V, 10%, SL
CX714	5-00014-501	390P	Capacitor, Ceramic Disc, 50V, 10%, SL

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
CY1	6-00010-620	4.000 MHZ	Crystal
D 101	3-00004-301	1N4148	Diode
D 102	3-00004-301	1N4148	Diode
D 103	3-00004-301	1N4148	Diode
D 104	3-00004-301	1N4148	Diode
D 105	3-00004-301	1N4148	Diode
D 106	3-00004-301	1N4148	Diode
D 201	3-00004-301	1N4148	Diode
D 202	3-00004-301	1N4148	Diode
D 203	3-00004-301	1N4148	Diode
D 204	3-00004-301	1N4148	Diode
D 301	3-00004-301	1N4148	Diode
D 302	3-00004-301	1N4148	Diode
D 303	3-00004-301	1N4148	Diode
D 401	3-00004-301	1N4148	Diode
D 402	3-00004-301	1N4148	Diode
D 403	3-00004-301	1N4148	Diode
D 404	3-00004-301	1N4148	Diode
D 501	3-00004-301	1N4148	Diode
D 502	3-00004-301	1N4148	Diode
D 701	3-00007-301	1N747A	Diode
D 702	3-00203-301	1N5711	Diode
D 703	3-00203-301	1N5711	Diode
D 704	3-00004-301	1N4148	Diode
D 901	3-00003-301	1N4007	Diode
D 902	3-00003-301	1N4007	Diode
D 903	3-00003-301	1N4007	Diode
D 904	3-00003-301	1N4007	Diode
FU1	6-00004-611	1A 3AG	Fuse
P 101	4-00006-440	20	Trim Pot, Single Turn, In-Line Leads
P 102	4-00012-441	20K	Pot, Multi-Turn Trim, 3/8" Square Top Ad
P 103	4-00012-441	20K	Pot, Multi-Turn Trim, 3/8" Square Top Ad
P 104	4-00013-441	50K	Pot, Multi-Turn Trim, 3/8" Square Top Ad
P 105	4-00014-441	5K	Pot, Multi-Turn Trim, 3/8" Square Top Ad
P 401	4-00011-441	10K	Pot, Multi-Turn Trim, 3/8" Square Top Ad
P 402	4-00011-441	10K	Pot, Multi-Turn Trim, 3/8" Square Top Ad
P 403	4-00011-441	10K	Pot, Multi-Turn Trim, 3/8" Square Top Ad
P 404	4-00011-441	10K	Pot, Multi-Turn Trim, 3/8" Square Top Ad
P 501	4-00002-440	100	Trim Pot, Single Turn, In-Line Leads
P 502	4-00002-440	100	Trim Pot, Single Turn, In-Line Leads
PC1	7-00036-701	SR500	Printed Circuit Board
Q 101	3-00016-323	2N6485	Transistor, TO-71 Package
Q 102	3-00016-323	2N6485	Transistor, TO-71 Package
Q 103	3-00031-325	MPSA18	Transistor, TO-92 Package
Q 201	3-00887-325	MPS2907A	Transistor, TO-92 Package
Q 202	3-00026-325	2N5210	Transistor, TO-92 Package
Q 502	3-00026-325	2N5210	Transistor, TO-92 Package
Q 701	3-00026-325	2N5210	Transistor, TO-92 Package
Q 702	3-00026-325	2N5210	Transistor, TO-92 Package
Q 703	3-00026-325	2N5210	Transistor, TO-92 Package
R 101	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
R 102	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%
R 103	4-00030-401	10	Resistor, Carbon Film, 1/4W, 5%
R 104	4-00031-401	100	Resistor, Carbon Film, 1/4W, 5%
R 105	4-00031-401	100	Resistor, Carbon Film, 1/4W, 5%
R 108	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 109	4-00199-407	6.81K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 110	4-00199-407	6.81K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 111	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 112	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 113	4-00145-407	110	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 114	4-00145-407	110	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 115	4-00047-401	2.2	Resistor, Carbon Film, 1/4W, 5%
R 116	4-00196-407	6.04K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 117	4-00210-407	9.09K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 118	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 119	4-00193-407	499	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 120	4-00180-407	301	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 121	4-00141-407	100	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 122	4-00141-407	100	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 126	4-00210-407	9.09K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 127	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 128	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 130	4-00082-401	470K	Resistor, Carbon Film, 1/4W, 5%
R 132	4-00082-401	470K	Resistor, Carbon Film, 1/4W, 5%
R 133	4-00179-407	30.1K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 134	4-00179-407	30.1K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 135	4-00131-407	1.00M	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 138	4-00052-401	20	Resistor, Carbon Film, 1/4W, 5%
R 139	4-00052-401	20	Resistor, Carbon Film, 1/4W, 5%
R 140	4-00150-407	13.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 141	4-00174-407	280	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 142	4-00168-407	22.6K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 143	4-00150-407	13.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 144	4-00157-407	16.9K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 145	4-00157-407	16.9K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 146	4-00193-407	499	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 147	4-00180-407	301	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 148	4-00141-407	100	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 149	4-00141-407	100	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 150	4-00179-407	30.1K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 151	4-00201-407	634	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 152	4-00195-407	54.9K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 153	4-00176-407	3.01K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 154	4-00178-407	3.83K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 155	4-00211-407	9.53K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 156	4-00193-407	499	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 157	4-00180-407	301	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 158	4-00141-407	100	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 159	4-00141-407	100	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 160	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%
R 161	4-00204-407	750	Resistor, Metal Film, 1/8W, 1%, 50PPM

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
R 162	4-00188-407	4.99K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 163	4-00035-401	10M	Resistor, Carbon Film, 1/4W, 5%
R 165	4-00215-407	909	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 166	4-00141-407	100	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 167	4-00215-407	909	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 168	4-00141-407	100	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 169	4-00134-407	1.24K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 170	4-00144-407	107	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 171	4-00182-407	33.2	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 172	4-00035-401	10M	Resistor, Carbon Film, 1/4W, 5%
R 173	4-00193-407	499	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 174	4-00180-407	301	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 175	4-00165-407	200	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 176	4-00211-407	9.53K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 177	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 178	4-00035-401	10M	Resistor, Carbon Film, 1/4W, 5%
R 201	4-00135-407	1.50K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 202	4-00194-407	5.11K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 203	4-00138-407	10.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 204	4-00138-407	10.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 205	4-00153-407	15.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 206	4-00138-407	10.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 207	4-00135-407	1.50K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 208	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 209	4-00150-407	13.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 210	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%
R 211	4-00138-407	10.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 212	4-00135-407	1.50K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 213	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 214	4-00150-407	13.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 215	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%
R 216	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 217	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 218	4-00035-401	10M	Resistor, Carbon Film, 1/4W, 5%
R 219	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 220	4-00177-407	3.48K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 221	4-00039-401	120K	Resistor, Carbon Film, 1/4W, 5%
R 222	4-00096-401	62K	Resistor, Carbon Film, 1/4W, 5%
R 223	4-00039-401	120K	Resistor, Carbon Film, 1/4W, 5%
R 224	4-00094-401	6.8K	Resistor, Carbon Film, 1/4W, 5%
R 225	4-00063-401	3.0K	Resistor, Carbon Film, 1/4W, 5%
R 226	4-00094-401	6.8K	Resistor, Carbon Film, 1/4W, 5%
R 227	4-00063-401	3.0K	Resistor, Carbon Film, 1/4W, 5%
R 228	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 229	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 301	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 302	4-00138-407	10.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 303	4-00138-407	10.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 304	4-00045-401	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 305	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 306	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
R 307	4-00040-401	13K	Resistor, Carbon Film, 1/4W, 5%
R 308	4-00193-407	499	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 309	4-00073-401	330K	Resistor, Carbon Film, 1/4W, 5%
R 310	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 311	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 312	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 313	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 314	4-00069-401	300K	Resistor, Carbon Film, 1/4W, 5%
R 315	4-00099-401	680K	Resistor, Carbon Film, 1/4W, 5%
R 316	4-00099-401	680K	Resistor, Carbon Film, 1/4W, 5%
R 317	4-00093-401	6.2K	Resistor, Carbon Film, 1/4W, 5%
R 318	4-00138-407	10.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 319	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 320	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 321	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 322	4-00170-407	249K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 323	4-00199-407	6.81K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 324	4-00199-407	6.81K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 325	4-00163-407	2.80K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 326	4-00150-407	13.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 327	4-00159-407	2.10K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 328	4-00029-401	1.8K	Resistor, Carbon Film, 1/4W, 5%
R 329	4-00088-401	51K	Resistor, Carbon Film, 1/4W, 5%
R 330	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 332	4-00161-407	2.49K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 333	4-00029-401	1.8K	Resistor, Carbon Film, 1/4W, 5%
R 334	4-00197-407	6.49K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 335	4-00088-401	51K	Resistor, Carbon Film, 1/4W, 5%
R 336	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 337	4-00035-401	10M	Resistor, Carbon Film, 1/4W, 5%
R 338	4-00030-401	10	Resistor, Carbon Film, 1/4W, 5%
R 339	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 340	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 341	4-00025-401	1.2M	Resistor, Carbon Film, 1/4W, 5%
R 342	4-00073-401	330K	Resistor, Carbon Film, 1/4W, 5%
R 343	4-00046-401	2.0M	Resistor, Carbon Film, 1/4W, 5%
R 344	4-00069-401	300K	Resistor, Carbon Film, 1/4W, 5%
R 345	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 346	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 347	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 348	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 349	4-00069-401	300K	Resistor, Carbon Film, 1/4W, 5%
R 350	4-00093-401	6.2K	Resistor, Carbon Film, 1/4W, 5%
R 351	4-00138-407	10.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 352	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 353	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 354	4-00203-407	75.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 355	4-00187-407	4.53K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 356	4-00160-407	2.26K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 357	4-00163-407	2.80K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 358	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
R 359	4-00045-401	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 360	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 361	4-00084-401	5.1K	Resistor, Carbon Film, 1/4W, 5%
R 362	4-00181-407	32.4K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 363	4-00132-407	1.10K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 364	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 365	4-00045-401	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 366	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 367	4-00151-407	130K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 368	4-00156-407	16.2K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 369	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 370	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 371	4-00030-401	10	Resistor, Carbon Film, 1/4W, 5%
R 372	4-00023-401	1.1M	Resistor, Carbon Film, 1/4W, 5%
R 373	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%
R 374	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%
R 375	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%
R 376	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%
R 377	4-00187-407	4.53K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 378	4-00045-401	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 401	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 402	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 403	4-00085-401	5.1M	Resistor, Carbon Film, 1/4W, 5%
R 404	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 405	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 406	4-00193-407	499	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 407	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 408	4-00131-407	1.00M	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 409	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 410	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 411	4-00193-407	499	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 412	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 413	4-00203-407	75.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 414	4-00080-401	47	Resistor, Carbon Film, 1/4W, 5%
R 415	4-00142-407	100K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 417	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 418	4-00132-407	1.10K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 419	4-00179-407	30.1K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 420	4-00183-407	348K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 421	4-00155-407	150K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 422	4-00184-407	37.4K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 423	4-00212-407	9.76K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 424	4-00161-407	2.49K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 425	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 426	4-00045-401	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 427	4-00131-407	1.00M	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 428	4-00131-407	1.00M	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 429	4-00146-407	110K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 430	4-00140-407	10.2K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 431	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 432	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
R 433	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 501	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 502	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 503	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 504	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 505	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 506	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 507	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 508	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 509	4-00218-408	10.00K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 510	4-00219-408	20.00K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 511	4-00218-408	10.00K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 512	4-00219-408	20.00K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 513	4-00166-407	200K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 514	4-00207-407	806K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 515	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 516	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 518	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 519	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 520	4-00086-401	51	Resistor, Carbon Film, 1/4W, 5%
R 521	4-00086-401	51	Resistor, Carbon Film, 1/4W, 5%
R 522	4-00218-408	10.00K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 523	4-00218-408	10.00K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 524	4-00078-401	39K	Resistor, Carbon Film, 1/4W, 5%
R 525	4-00059-401	22K	Resistor, Carbon Film, 1/4W, 5%
R 526	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 527	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 528	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 529	4-00057-401	220	Resistor, Carbon Film, 1/4W, 5%
R 530	4-00210-407	9.09K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 531	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 532	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 533	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 534	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 535	4-00057-401	220	Resistor, Carbon Film, 1/4W, 5%
R 536	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 537	4-00057-401	220	Resistor, Carbon Film, 1/4W, 5%
R 538	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 539	4-00057-401	220	Resistor, Carbon Film, 1/4W, 5%
R 540	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 541	4-00057-401	220	Resistor, Carbon Film, 1/4W, 5%
R 542	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 543	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 544	4-00042-401	15K	Resistor, Carbon Film, 1/4W, 5%
R 545	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 546	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 547	4-00042-401	15K	Resistor, Carbon Film, 1/4W, 5%
R 548	4-00054-401	200K	Resistor, Carbon Film, 1/4W, 5%
R 549	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 701	4-00031-401	100	Resistor, Carbon Film, 1/4W, 5%
R 702	4-00079-401	4.7K	Resistor, Carbon Film, 1/4W, 5%

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
R 703	4-00027-401	1.5K	Resistor, Carbon Film, 1/4W, 5%
R 705	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 706	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 707	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 708	4-00069-401	300K	Resistor, Carbon Film, 1/4W, 5%
R 709	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 710	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 711	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 712	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 801	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 802	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 803	4-00065-401	3.3K	Resistor, Carbon Film, 1/4W, 5%
R 901	4-00107-402	10	Resistor, Carbon Comp, 1/2W, 5%
R 902	4-00107-402	10	Resistor, Carbon Comp, 1/2W, 5%
R 903	4-00060-401	240	Resistor, Carbon Film, 1/4W, 5%
R 904	4-00024-401	1.2K	Resistor, Carbon Film, 1/4W, 5%
R 905	4-00024-401	1.2K	Resistor, Carbon Film, 1/4W, 5%
R 906	4-00060-401	240	Resistor, Carbon Film, 1/4W, 5%
R 907	4-00107-402	10	Resistor, Carbon Comp, 1/2W, 5%
R 908	4-00107-402	10	Resistor, Carbon Comp, 1/2W, 5%
R 909	4-00053-401	200	Resistor, Carbon Film, 1/4W, 5%
R 910	4-00063-401	3.0K	Resistor, Carbon Film, 1/4W, 5%
R 911	4-00063-401	3.0K	Resistor, Carbon Film, 1/4W, 5%
R 912	4-00053-401	200	Resistor, Carbon Film, 1/4W, 5%
R 913	4-00107-402	10	Resistor, Carbon Comp, 1/2W, 5%
R 914	4-00107-402	10	Resistor, Carbon Comp, 1/2W, 5%
RN401	4-00220-420	10KX8	Resistor Network, DIP, 1/4W,2%,8 Ind
RN801	4-00225-425	100KX9	Resistor Network SIP 1/4W 2% (Common)
RN802	4-00225-425	100KX9	Resistor Network SIP 1/4W 2% (Common)
SO702	1-00026-150	28 PIN 600 MIL	Socket, THRU-HOLE
SW1	2-00014-207	SPSTX8	Switch, DIP
SW2	2-00014-207	SPSTX8	Switch, DIP
SW601	2-00017-216	4PDT	Switch, Rocker, PCB Mount (LHS of 510)
SW602	2-00004-213	DPDT	Switch, Rocker, PCB Mount (RHS of 510)
T 1	6-00007-610	SR510/530	Transformer
U 101	8-00085-860	SR513 ASSY	SRS sub assemblies
U 102	8-00085-860	SR513 ASSY	SRS sub assemblies
U 103	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 104	3-00118-325	78L15	Transistor, TO-92 Package
U 105	3-00124-325	79L15	Transistor, TO-92 Package
U 106	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 107	3-00130-340	5532A	Integrated Circuit (Thru-hole Pkg)
U 108	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 109	3-00088-340	LF353	Integrated Circuit (Thru-hole Pkg)
U 110	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 111	3-00089-340	LF357	Integrated Circuit (Thru-hole Pkg)
U 112	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 113	3-00089-340	LF357	Integrated Circuit (Thru-hole Pkg)
U 114	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 115	3-00089-340	LF357	Integrated Circuit (Thru-hole Pkg)
U 117	3-00088-340	LF353	Integrated Circuit (Thru-hole Pkg)

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
U 118	3-00130-340	5532A	Integrated Circuit (Thru-hole Pkg)
U 201	3-00087-340	LF347	Integrated Circuit (Thru-hole Pkg)
U 202	3-00093-340	LM13600	Integrated Circuit (Thru-hole Pkg)
U 203	3-00073-340	CD4052	Integrated Circuit (Thru-hole Pkg)
U 204	3-00073-340	CD4052	Integrated Circuit (Thru-hole Pkg)
U 205	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 206	3-00038-340	74HC139	Integrated Circuit (Thru-hole Pkg)
U 207	3-00038-340	74HC139	Integrated Circuit (Thru-hole Pkg)
U 208	3-00087-340	LF347	Integrated Circuit (Thru-hole Pkg)
U 301	3-00088-340	LF353	Integrated Circuit (Thru-hole Pkg)
U 303	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 304	3-00094-340	LM311	Integrated Circuit (Thru-hole Pkg)
U 305	3-00075-340	CD4538	Integrated Circuit (Thru-hole Pkg)
U 306	3-00072-340	CD4046	Integrated Circuit (Thru-hole Pkg)
U 307	3-00093-340	LM13600	Integrated Circuit (Thru-hole Pkg)
U 308	3-00066-340	CA3140E	Integrated Circuit (Thru-hole Pkg)
U 309	3-00093-340	LM13600	Integrated Circuit (Thru-hole Pkg)
U 310	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 311	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 312	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 313	3-00049-340	74HC74	Integrated Circuit (Thru-hole Pkg)
U 314	3-00094-340	LM311	Integrated Circuit (Thru-hole Pkg)
U 315	3-00094-340	LM311	Integrated Circuit (Thru-hole Pkg)
U 316	3-00072-340	CD4046	Integrated Circuit (Thru-hole Pkg)
U 317	3-00093-340	LM13600	Integrated Circuit (Thru-hole Pkg)
U 318	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 319	3-00066-340	CA3140E	Integrated Circuit (Thru-hole Pkg)
U 320	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 321	3-00066-340	CA3140E	Integrated Circuit (Thru-hole Pkg)
U 322	3-00093-340	LM13600	Integrated Circuit (Thru-hole Pkg)
U 323	3-00093-340	LM13600	Integrated Circuit (Thru-hole Pkg)
U 324	3-00094-340	LM311	Integrated Circuit (Thru-hole Pkg)
U 325	3-00091-340	LF412	Integrated Circuit (Thru-hole Pkg)
U 326	3-00068-340	CD4018	Integrated Circuit (Thru-hole Pkg)
U 327	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 328	3-00094-340	LM311	Integrated Circuit (Thru-hole Pkg)
U 329	3-00094-340	LM311	Integrated Circuit (Thru-hole Pkg)
U 401	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 402	3-00091-340	LF412	Integrated Circuit (Thru-hole Pkg)
U 403	3-00090-340	LF411	Integrated Circuit (Thru-hole Pkg)
U 404	3-00106-340	LT1007	Integrated Circuit (Thru-hole Pkg)
U 405	3-00074-340	CD4066	Integrated Circuit (Thru-hole Pkg)
U 406	3-00057-340	AD534	Integrated Circuit (Thru-hole Pkg)
U 407	3-00090-340	LF411	Integrated Circuit (Thru-hole Pkg)
U 408	3-00106-340	LT1007	Integrated Circuit (Thru-hole Pkg)
U 409	3-00090-340	LF411	Integrated Circuit (Thru-hole Pkg)
U 410	3-00084-340	ICL7650	Integrated Circuit (Thru-hole Pkg)
U 411	3-00126-335	51A05	Relay
U 412	3-00126-335	51A05	Relay
U 413	3-00126-335	51A05	Relay
U 414	3-00126-335	51A05	Relay

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
U 415	3-00126-335	51A05	Relay
U 416	3-00084-340	ICL7650	Integrated Circuit (Thru-hole Pkg)
U 417	3-00126-335	51A05	Relay
U 418	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 419	3-00090-340	LF411	Integrated Circuit (Thru-hole Pkg)
U 420	3-00064-340	CA3081	Integrated Circuit (Thru-hole Pkg)
U 421	3-00035-340	74C74	Integrated Circuit (Thru-hole Pkg)
U 501	3-00087-340	LF347	Integrated Circuit (Thru-hole Pkg)
U 502	3-00058-340	AD7524	Integrated Circuit (Thru-hole Pkg)
U 503	3-00046-340	74HC374	Integrated Circuit (Thru-hole Pkg)
U 504	3-00077-340	DG528	Integrated Circuit (Thru-hole Pkg)
U 505	3-00059-340	AD7542JN	Integrated Circuit (Thru-hole Pkg)
U 506	3-00058-340	AD7524	Integrated Circuit (Thru-hole Pkg)
U 507	3-00077-340	DG528	Integrated Circuit (Thru-hole Pkg)
U 508	3-00087-340	LF347	Integrated Circuit (Thru-hole Pkg)
U 509	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 510	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 511	3-00087-340	LF347	Integrated Circuit (Thru-hole Pkg)
U 512	3-00087-340	LF347	Integrated Circuit (Thru-hole Pkg)
U 513	3-00087-340	LF347	Integrated Circuit (Thru-hole Pkg)
U 514	3-00094-340	LM311	Integrated Circuit (Thru-hole Pkg)
U 515	3-00087-340	LF347	Integrated Circuit (Thru-hole Pkg)
U 516	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 517	3-00092-340	LH0071	Integrated Circuit (Thru-hole Pkg)
U 701	3-00132-340	Z80A-CPU	Integrated Circuit (Thru-hole Pkg)
U 703	3-00081-341	2KX8-100	STATIC RAM, I.C.
U 704	3-00491-340	UPD71054C	Integrated Circuit (Thru-hole Pkg)
U 705	3-00037-340	74HC138	Integrated Circuit (Thru-hole Pkg)
U 706	3-00037-340	74HC138	Integrated Circuit (Thru-hole Pkg)
U 707	3-00037-340	74HC138	Integrated Circuit (Thru-hole Pkg)
U 708	3-00040-340	74HC157	Integrated Circuit (Thru-hole Pkg)
U 709	3-00049-340	74HC74	Integrated Circuit (Thru-hole Pkg)
U 710	3-00045-340	74HC32	Integrated Circuit (Thru-hole Pkg)
U 711	3-00051-340	74HCU04	Integrated Circuit (Thru-hole Pkg)
U 712	3-00047-340	74HC4040	Integrated Circuit (Thru-hole Pkg)
U 713	3-00049-340	74HC74	Integrated Circuit (Thru-hole Pkg)
U 714	3-00042-340	74HC175	Integrated Circuit (Thru-hole Pkg)
U 715	3-00042-340	74HC175	Integrated Circuit (Thru-hole Pkg)
U 716	3-00044-340	74HC244	Integrated Circuit (Thru-hole Pkg)
U 717	3-00046-340	74HC374	Integrated Circuit (Thru-hole Pkg)
U 718	3-00039-340	74HC14	Integrated Circuit (Thru-hole Pkg)
U 719	3-00046-340	74HC374	Integrated Circuit (Thru-hole Pkg)
U 720	3-00046-340	74HC374	Integrated Circuit (Thru-hole Pkg)
U 721	3-00046-340	74HC374	Integrated Circuit (Thru-hole Pkg)
U 722	3-00045-340	74HC32	Integrated Circuit (Thru-hole Pkg)
U 801	3-00493-340	UPD71051C	Integrated Circuit (Thru-hole Pkg)
U 802	3-00111-340	MC68488	Integrated Circuit (Thru-hole Pkg)
U 803	3-00044-340	74HC244	Integrated Circuit (Thru-hole Pkg)
U 804	3-00044-340	74HC244	Integrated Circuit (Thru-hole Pkg)
U 805	3-00049-340	74HC74	Integrated Circuit (Thru-hole Pkg)
U 806	3-00109-340	MC1488	Integrated Circuit (Thru-hole Pkg)

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
U 807	3-00110-340	MC1489	Integrated Circuit (Thru-hole Pkg)
U 808	3-00078-340	DS75160A	Integrated Circuit (Thru-hole Pkg)
U 809	3-00117-325	78L12	Transistor, TO-92 Package
U 810	3-00123-325	79L12	Transistor, TO-92 Package
U 811	3-00079-340	DS75161A	Integrated Circuit (Thru-hole Pkg)
U 901	3-00095-331	LM317K	Voltage Regulator, TO-3 Metal Can
U 902	3-00099-331	LM337K	Voltage Regulator, TO-3 Metal Can
U 903	3-00114-329	7815	Voltage Reg., TO-220 (TAB) Package
U 904	3-00114-329	7815	Voltage Reg., TO-220 (TAB) Package
U 905	3-00114-329	7815	Voltage Reg., TO-220 (TAB) Package
U 906	3-00120-329	7915	Voltage Reg., TO-220 (TAB) Package
U 907	3-00120-329	7915	Voltage Reg., TO-220 (TAB) Package
U 908	3-00120-329	7915	Voltage Reg., TO-220 (TAB) Package
U 909	3-00113-340	7805CK	Integrated Circuit (Thru-hole Pkg)
U 910	3-00116-325	78L05	Transistor, TO-92 Package
U 911	3-00096-340	LM317L	Integrated Circuit (Thru-hole Pkg)
U 912	3-00100-340	LM337L	Integrated Circuit (Thru-hole Pkg)
Z 0	0-00005-007	SR530	Heat Sinks
Z 0	0-00014-002	6J4	Power_Entry Hardware
Z 0	0-00016-000	TIE ANCHOR	Hardware, Misc.
Z 0	0-00017-002	TRANSCOVER	Power_Entry Hardware
Z 0	0-00019-003	MICA	Insulators
Z 0	0-00025-005	3/8"	Lugs
Z 0	0-00043-011	4-40 KEP	Nut, Kep
Z 0	0-00048-011	6-32 KEP	Nut, Kep
Z 0	0-00064-027	6-20X5/8P	Screw, Sheet Metal
Z 0	0-00079-031	4-40X3/16 M/F	Standoff
Z 0	0-00084-032	36154	Termination
Z 0	0-00089-033	4"	Tie
Z 0	0-00095-040	#4 FLAT	Washer, Flat
Z 0	0-00096-041	#4 SPLIT	Washer, Split
Z 0	0-00113-053	10" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00117-053	12" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00119-053	15" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00128-053	4" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00130-050	5-5/8" #18	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-00132-053	6-1/2" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00136-053	8-1/2" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00153-057	GROMMET2	Grommet
Z 0	0-00185-021	6-32X3/8PP	Screw, Panhead Phillips
Z 0	0-00187-021	4-40X1/4PP	Screw, Panhead Phillips
Z 0	0-00207-003	TO-5	Insulators
Z 0	0-00222-021	6-32X1/4PP	Screw, Panhead Phillips
Z 0	0-00225-052	17" #22 BLACK	Wire #22 UL1007
Z 0	0-00226-052	17" #22 WHITE	Wire #22 UL1007
Z 0	0-00227-052	17" #22 RED	Wire #22 UL1007
Z 0	0-00228-052	17" #22 GREEN	Wire #22 UL1007
Z 0	0-00231-043	#4 SHOULDER	Washer, nylon
Z 0	0-00241-021	4-40X3/16PP	Screw, Panhead Phillips
Z 0	0-00249-021	6-32X1-1/2PP	Screw, Panhead Phillips
Z 0	0-00256-043	#6 SHOULDER	Washer, nylon

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
Z 0	0-00257-000	HANDLE3	Hardware, Misc.
Z 0	0-00371-026	4-40X3/16PF	Screw, Black, All Types
Z 0	0-00500-000	554808-1	Hardware, Misc.
Z 0	0-00521-048	3" #18	Wire, #18 UL1015 Strip 3/8 x 3/8 No Tin
Z 0	0-00526-048	10-1/2" #18	Wire, #18 UL1015 Strip 3/8 x 3/8 No Tin
Z 0	0-00893-026	8-32X3/8PF	Screw, Black, All Types
Z 0	1-00003-120	BNC	Connector, BNC
Z 0	1-00010-130	20 PIN ELH	Connector, Male
Z 0	1-00012-135	20 PIN CARD	Connector, Card Edge
Z 0	1-00013-135	40 PIN CARD	Connector, Card Edge
Z 0	1-00029-150	TO-3	Socket, THRU-HOLE
Z 0	1-00053-172	USA	Line Cord
Z 0	7-00201-720	SR500-32	Fabricated Part
Z 0	7-00202-720	SR500-33	Fabricated Part
Z 0	7-00210-720	SR530-22	Fabricated Part
Z 0	7-00212-720	SR530-26	Fabricated Part
Z 0	7-00213-720	SR530-27	Fabricated Part
Z 0	7-00214-720	SR530-28	Fabricated Part
Z 0	9-00144-907	3/32"BLACK	Shrink Tubing
Z 0	9-00188-917	SR510/530 SER	Product Labels
Z 0	9-00216-907	1/8" BLACK	Shrink Tubing
Z 0	9-00217-907	3/16" BLACK	Shrink Tubing

Front Panel Board Parts List

REF.	SRS part#	VALUE	DESCRIPTION
C 607	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 608	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 609	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 610	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 6100	5-00019-501	68P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 6101	5-00019-501	68P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 6102	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 6103	5-00052-512	.01U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 6105	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 6106	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
D 601	3-00004-301	1N4148	Diode
D 602	3-00004-301	1N4148	Diode
D 603	3-00004-301	1N4148	Diode
D 604	3-00004-301	1N4148	Diode
DS601	3-00012-306	GREEN	LED, Rectangular
DS602	3-00012-306	GREEN	LED, Rectangular
DS603	3-00012-306	GREEN	LED, Rectangular
DS604	3-00012-306	GREEN	LED, Rectangular
DS605	3-00012-306	GREEN	LED, Rectangular
DS606	3-00012-306	GREEN	LED, Rectangular
DS607	3-00012-306	GREEN	LED, Rectangular
DS608	3-00012-306	GREEN	LED, Rectangular
DS609	3-00012-306	GREEN	LED, Rectangular
DS610	3-00012-306	GREEN	LED, Rectangular

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
DS611	3-00012-306	GREEN	LED, Rectangular
DS612	3-00012-306	GREEN	LED, Rectangular
DS613	3-00012-306	GREEN	LED, Rectangular
DS614	3-00012-306	GREEN	LED, Rectangular
DS615	3-00012-306	GREEN	LED, Rectangular
DS616	3-00012-306	GREEN	LED, Rectangular
DS617	3-00012-306	GREEN	LED, Rectangular
DS618	3-00012-306	GREEN	LED, Rectangular
DS619	3-00012-306	GREEN	LED, Rectangular
DS620	3-00012-306	GREEN	LED, Rectangular
DS621	3-00012-306	GREEN	LED, Rectangular
DS622	3-00012-306	GREEN	LED, Rectangular
DS623	3-00012-306	GREEN	LED, Rectangular
DS624	3-00012-306	GREEN	LED, Rectangular
DS625	3-00012-306	GREEN	LED, Rectangular
DS626	3-00012-306	GREEN	LED, Rectangular
DS627	3-00012-306	GREEN	LED, Rectangular
DS628	3-00012-306	GREEN	LED, Rectangular
DS629	3-00012-306	GREEN	LED, Rectangular
DS630	3-00012-306	GREEN	LED, Rectangular
DS631	3-00012-306	GREEN	LED, Rectangular
DS632	3-00012-306	GREEN	LED, Rectangular
DS633	3-00012-306	GREEN	LED, Rectangular
DS634	3-00012-306	GREEN	LED, Rectangular
DS635	3-00012-306	GREEN	LED, Rectangular
DS636	3-00012-306	GREEN	LED, Rectangular
DS637	3-00012-306	GREEN	LED, Rectangular
DS638	3-00013-306	RED	LED, Rectangular
DS639	3-00013-306	RED	LED, Rectangular
DS640	3-00013-306	RED	LED, Rectangular
DS641	3-00012-306	GREEN	LED, Rectangular
DS642	3-00012-306	GREEN	LED, Rectangular
DS643	3-00012-306	GREEN	LED, Rectangular
DS644	3-00012-306	GREEN	LED, Rectangular
DS645	3-00012-306	GREEN	LED, Rectangular
DS646	3-00012-306	GREEN	LED, Rectangular
DS647	3-00012-306	GREEN	LED, Rectangular
DS648	3-00012-306	GREEN	LED, Rectangular
DS649	3-00012-306	GREEN	LED, Rectangular
DS650	3-00012-306	GREEN	LED, Rectangular
DS651	3-00012-306	GREEN	LED, Rectangular
DS652	3-00012-306	GREEN	LED, Rectangular
DS653	3-00012-306	GREEN	LED, Rectangular
DS654	3-00012-306	GREEN	LED, Rectangular
DS655	3-00012-306	GREEN	LED, Rectangular
DS656	3-00012-306	GREEN	LED, Rectangular
DS657	3-00012-306	GREEN	LED, Rectangular
DS658	3-00012-306	GREEN	LED, Rectangular
DS659	3-00012-306	GREEN	LED, Rectangular
DS660	3-00012-306	GREEN	LED, Rectangular
DS661	3-00012-306	GREEN	LED, Rectangular

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
DS662	3-00012-306	GREEN	LED, Rectangular
DS663	3-00012-306	GREEN	LED, Rectangular
DS664	3-00012-306	GREEN	LED, Rectangular
DS665	3-00012-306	GREEN	LED, Rectangular
DS666	3-00012-306	GREEN	LED, Rectangular
DS667	3-00012-306	GREEN	LED, Rectangular
DS668	3-00012-306	GREEN	LED, Rectangular
DS669	3-00012-306	GREEN	LED, Rectangular
DS670	3-00012-306	GREEN	LED, Rectangular
DS671	3-00012-306	GREEN	LED, Rectangular
LD1	8-00001-820	FE0206	LCD Display
LD2	8-00001-820	FE0206	LCD Display
LD3	8-00001-820	FE0206	LCD Display
M 1	8-00003-801	-10/0/10S	Analog Meter
M 2	8-00003-801	-10/0/10S	Analog Meter
PB601	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB602	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB603	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB604	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB605	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB606	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB607	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB608	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB609	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB610	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB611	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB612	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB613	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB614	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB615	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB616	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB617	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB618	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB619	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB620	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB621	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB622	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB623	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB624	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB625	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB626	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB627	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB628	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB629	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB630	2-00001-201	D6-01-01	Switch, Momentary Push Button
PB631	2-00001-201	D6-01-01	Switch, Momentary Push Button
PC1	7-00039-701	SR521	Printed Circuit Board
R 601	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 602	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
RN601	4-00227-425	22KX9	Resistor Network SIP 1/4W 2% (Common)
RN602	4-00226-425	150X9	Resistor Network SIP 1/4W 2% (Common)

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
RN603	4-00226-425	150X9	Resistor Network SIP 1/4W 2% (Common)
RN604	4-00222-425	150X7	Resistor Network SIP 1/4W 2% (Common)
U 601	3-00086-340	ICM7211AM	Integrated Circuit (Thru-hole Pkg)
U 602	3-00086-340	ICM7211AM	Integrated Circuit (Thru-hole Pkg)
U 603	3-00086-340	ICM7211AM	Integrated Circuit (Thru-hole Pkg)
U 604	3-00071-340	CD4030	Integrated Circuit (Thru-hole Pkg)
U 605	3-00071-340	CD4030	Integrated Circuit (Thru-hole Pkg)
U 606	3-00071-340	CD4030	Integrated Circuit (Thru-hole Pkg)
U 607	3-00046-340	74HC374	Integrated Circuit (Thru-hole Pkg)
U 608	3-00042-340	74HC175	Integrated Circuit (Thru-hole Pkg)
U 609	3-00044-340	74HC244	Integrated Circuit (Thru-hole Pkg)
U 610	3-00053-340	74LS164	Integrated Circuit (Thru-hole Pkg)
U 611	3-00053-340	74LS164	Integrated Circuit (Thru-hole Pkg)
U 612	3-00053-340	74LS164	Integrated Circuit (Thru-hole Pkg)
U 613	3-00053-340	74LS164	Integrated Circuit (Thru-hole Pkg)
U 614	3-00053-340	74LS164	Integrated Circuit (Thru-hole Pkg)
U 615	3-00053-340	74LS164	Integrated Circuit (Thru-hole Pkg)
U 616	3-00053-340	74LS164	Integrated Circuit (Thru-hole Pkg)
U 617	3-00053-340	74LS164	Integrated Circuit (Thru-hole Pkg)
U 618	3-00053-340	74LS164	Integrated Circuit (Thru-hole Pkg)
Z 0	0-00042-010	4-40 HEX	Nut, Hex
Z 0	0-00077-030	3/16"X5/16"NYLN	Spacer
Z 0	0-00102-042	#10 LOCK	Washer, lock
Z 0	0-00104-043	#4 NYLON	Washer, nylon
Z 0	0-00106-044	CLEAR	Window
Z 0	0-00111-053	1-3/4"#24B	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00112-053	1-3/4"#24R	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00117-053	12" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00118-053	14" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00119-053	15" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00126-053	3-1/2" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00128-053	4" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00129-053	5" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00136-053	8-1/2" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00139-054	9" #26 X20	Wire #26 UL1061
Z 0	0-00203-032	323914	Termination
Z 0	1-00011-130	20 PIN IDP	Connector, Male
Z 0	1-00073-120	INSL	Connector, BNC
Z 0	1-00145-131	20 PIN DIF POL	Connector, Female
Z 0	7-00305-710	SR530-31	Front Panel
Z 0	7-00306-709	SR530-32-36	Lexan Overlay
Z 0	9-00815-924	DBL-SIDED 1/2"	Tape, All types

Quad Board Parts List

REF.	SRS part#	VALUE	DESCRIPTION
C 1001	5-00016-501	470P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 1002	5-00038-509	10U	Capacitor, Electrolytic, 50V, 20%, Rad
C 1004	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1005	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
C 1006	5-00058-512	.33U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1007	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 1008	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 1009	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 1010	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 1011	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 1012	5-00035-521	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 1013	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 1014	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 1015	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 1016	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 1017	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 1018	5-00008-501	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 1101	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1102	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 1103	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 1104	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1105	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1106	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 1107	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 1108	5-00003-501	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 1109	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1110	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1111	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1112	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1113	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 1114	5-00053-512	.033U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1115	5-00072-513	10U	Capacitor, Mylar/Poly, 50V, 5%, Rad
C 1116	5-00056-512	.1U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1117	5-00060-512	1.0U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1120	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 1121	5-00013-501	33P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 1122	5-00013-501	33P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 1123	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1124	5-00054-512	.047U	Cap, Stacked Metal Film 50V 5% -40/+85c
C 1125	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 1126	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 1201	5-00012-501	330P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 1202	5-00136-519	.01U	Capacitor, Polystyrene, 50V, 5%, Rad
C 1203	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 1204	5-00049-566	.001U	Cap, Polyester Film 50V 5% -40/+85c Rad
C 1205	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 1206	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 1207	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 1208	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
D 1001	3-00004-301	1N4148	Diode
D 1002	3-00004-301	1N4148	Diode
D 1103	3-00004-301	1N4148	Diode
D 1104	3-00004-301	1N4148	Diode
P 1101	4-00016-445	10K	Pot, Multi-Turn, Side Adjust
P 1102	4-00016-445	10K	Pot, Multi-Turn, Side Adjust

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
P 1103	4-00016-445	10K	Pot, Multi-Turn, Side Adjust
P 1104	4-00016-445	10K	Pot, Multi-Turn, Side Adjust
P 1201	4-00016-445	10K	Pot, Multi-Turn, Side Adjust
P 1202	4-00016-445	10K	Pot, Multi-Turn, Side Adjust
PC1	7-00040-701	SR522	Printed Circuit Board
Q 1201	3-00026-325	2N5210	Transistor, TO-92 Package
R 1001	4-00045-401	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 1002	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 1003	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 1004	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 1005	4-00069-401	300K	Resistor, Carbon Film, 1/4W, 5%
R 1006	4-00093-401	6.2K	Resistor, Carbon Film, 1/4W, 5%
R 1007	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 1008	4-00069-401	300K	Resistor, Carbon Film, 1/4W, 5%
R 1009	4-00046-401	2.0M	Resistor, Carbon Film, 1/4W, 5%
R 1010	4-00073-401	330K	Resistor, Carbon Film, 1/4W, 5%
R 1011	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 1012	4-00138-407	10.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1013	4-00203-407	75.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1014	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 1015	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 1016	4-00187-407	4.53K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1017	4-00160-407	2.26K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1018	4-00163-407	2.80K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1019	4-00084-401	5.1K	Resistor, Carbon Film, 1/4W, 5%
R 1020	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 1021	4-00181-407	32.4K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1022	4-00132-407	1.10K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1023	4-00151-407	130K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1024	4-00156-407	16.2K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1025	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1026	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1027	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 1028	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 1029	4-00045-401	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 1030	4-00088-401	51K	Resistor, Carbon Film, 1/4W, 5%
R 1031	4-00030-401	10	Resistor, Carbon Film, 1/4W, 5%
R 1032	4-00030-401	10	Resistor, Carbon Film, 1/4W, 5%
R 1033	4-00030-401	10	Resistor, Carbon Film, 1/4W, 5%
R 1034	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%
R 1035	4-00033-404	100M	Resistor, Carbon Comp, 1/4W, 5%
R 1036	4-00187-407	4.53K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1037	4-00045-401	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 1101	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 1102	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 1103	4-00085-401	5.1M	Resistor, Carbon Film, 1/4W, 5%
R 1104	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 1105	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 1106	4-00193-407	499	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1107	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1108	4-00131-407	1.00M	Resistor, Metal Film, 1/8W, 1%, 50PPM

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
R 1109	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 1110	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 1111	4-00193-407	499	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1112	4-00217-408	1.000K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 1113	4-00203-407	75.0K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1114	4-00080-401	47	Resistor, Carbon Film, 1/4W, 5%
R 1115	4-00142-407	100K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1116	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 1117	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 1118	4-00132-407	1.10K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1119	4-00179-407	30.1K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1120	4-00183-407	348K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1121	4-00155-407	150K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1122	4-00184-407	37.4K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1123	4-00212-407	9.76K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1124	4-00161-407	2.49K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1125	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 1126	4-00045-401	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 1127	4-00131-407	1.00M	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1128	4-00131-407	1.00M	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1129	4-00146-407	110K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1130	4-00140-407	10.2K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1132	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 1133	4-00021-401	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 1201	4-00218-408	10.00K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 1202	4-00219-408	20.00K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 1203	4-00218-408	10.00K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 1204	4-00219-408	20.00K	Resistor, Metal Film, 1/8W, 0.1%, 25ppm
R 1205	4-00210-407	9.09K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1206	4-00130-407	1.00K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 1207	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 1208	4-00032-401	100K	Resistor, Carbon Film, 1/4W, 5%
R 1209	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 1210	4-00057-401	220	Resistor, Carbon Film, 1/4W, 5%
R 1211	4-00034-401	10K	Resistor, Carbon Film, 1/4W, 5%
R 1212	4-00057-401	220	Resistor, Carbon Film, 1/4W, 5%
U 1001	3-00094-340	LM311	Integrated Circuit (Thru-hole Pkg)
U 1002	3-00072-340	CD4046	Integrated Circuit (Thru-hole Pkg)
U 1003	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 1004	3-00094-340	LM311	Integrated Circuit (Thru-hole Pkg)
U 1005	3-00093-340	LM13600	Integrated Circuit (Thru-hole Pkg)
U 1006	3-00066-340	CA3140E	Integrated Circuit (Thru-hole Pkg)
U 1007	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 1008	3-00066-340	CA3140E	Integrated Circuit (Thru-hole Pkg)
U 1009	3-00093-340	LM13600	Integrated Circuit (Thru-hole Pkg)
U 1010	3-00093-340	LM13600	Integrated Circuit (Thru-hole Pkg)
U 1011	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 1012	3-00094-340	LM311	Integrated Circuit (Thru-hole Pkg)
U 1013	3-00068-340	CD4018	Integrated Circuit (Thru-hole Pkg)
U 1014	3-00091-340	LF412	Integrated Circuit (Thru-hole Pkg)
U 1101	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)

SR530 COMPONENT PARTS LIST

REF.	SRS part#	VALUE	DESCRIPTION
U 1102	3-00091-340	LF412	Integrated Circuit (Thru-hole Pkg)
U 1103	3-00090-340	LF411	Integrated Circuit (Thru-hole Pkg)
U 1104	3-00106-340	LT1007	Integrated Circuit (Thru-hole Pkg)
U 1105	3-00074-340	CD4066	Integrated Circuit (Thru-hole Pkg)
U 1106	3-00057-340	AD534	Integrated Circuit (Thru-hole Pkg)
U 1107	3-00090-340	LF411	Integrated Circuit (Thru-hole Pkg)
U 1108	3-00106-340	LT1007	Integrated Circuit (Thru-hole Pkg)
U 1109	3-00090-340	LF411	Integrated Circuit (Thru-hole Pkg)
U 1110	3-00084-340	ICL7650	Integrated Circuit (Thru-hole Pkg)
U 1111	3-00126-335	51A05	Relay
U 1112	3-00126-335	51A05	Relay
U 1113	3-00126-335	51A05	Relay
U 1114	3-00126-335	51A05	Relay
U 1115	3-00126-335	51A05	Relay
U 1116	3-00084-340	ICL7650	Integrated Circuit (Thru-hole Pkg)
U 1117	3-00126-335	51A05	Relay
U 1118	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 1119	3-00090-340	LF411	Integrated Circuit (Thru-hole Pkg)
U 1120	3-00088-340	LF353	Integrated Circuit (Thru-hole Pkg)
U 1121	3-00035-340	74C74	Integrated Circuit (Thru-hole Pkg)
U 1201	3-00058-340	AD7524	Integrated Circuit (Thru-hole Pkg)
U 1202	3-00087-340	LF347	Integrated Circuit (Thru-hole Pkg)
U 1203	3-00076-340	DG211	Integrated Circuit (Thru-hole Pkg)
U 1204	3-00090-340	LF411	Integrated Circuit (Thru-hole Pkg)
U 1205	3-00090-340	LF411	Integrated Circuit (Thru-hole Pkg)

Miscellaneous Parts List

REF.	SRS part#	VALUE	DESCRIPTION
U 702	3-00161-342	27128-150	EPROM/PROM, I.C.
Z 0	0-00045-013	4-40 MINI	Nut, Mini
Z 0	0-00078-031	4-40X1 M/F	Standoff
Z 0	0-00167-023	6-32X1/2RP	Screw, Roundhead Phillips
Z 0	0-00179-000	RIGHT FOOT	Hardware, Misc.
Z 0	0-00180-000	LEFT FOOT	Hardware, Misc.
Z 0	0-00185-021	6-32X3/8PP	Screw, Panhead Phillips
Z 0	0-00187-021	4-40X1/4PP	Screw, Panhead Phillips
Z 0	0-00204-000	REAR FOOT	Hardware, Misc.
Z 0	0-00209-021	4-40X3/8PP	Screw, Panhead Phillips
Z 0	0-00247-026	6-32X1/4 TRUSSP	Screw, Black, All Types
Z 0	0-00248-026	10-32X3/8TRUSSP	Screw, Black, All Types
Z 0	0-00371-026	4-40X3/16PF	Screw, Black, All Types
Z 0	6-00054-611	.375A 3AG	Fuse
Z 0	7-00147-720	BAIL	Fabricated Part
Z 0	7-00203-720	SR500-34	Fabricated Part
Z 0	7-00204-720	SR500-35	Fabricated Part
Z 0	7-00211-720	SR530-25	Fabricated Part
Z 0	7-00215-720	SR530-29	Fabricated Part
Z 0	7-00216-720	SR530-30	Fabricated Part

SR530 COMPONENT PARTS LIST