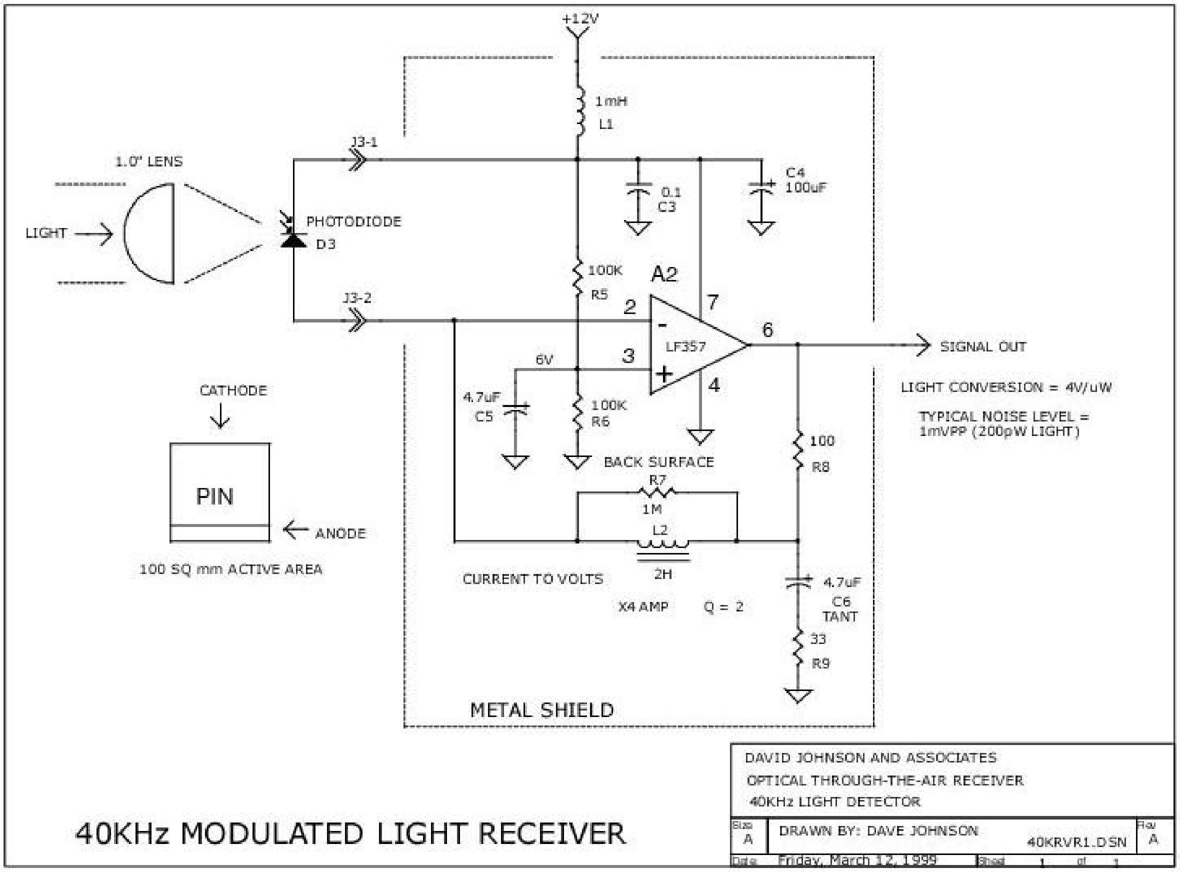
+12V
1mH
L1
J3-1
1.0" LENS
C4
100uF
0.1
C3
LIGHT
PHOTODIODE
D3
100K
R5
A2
J3-2
2
7
6
LF357
SIGNAL OUT
6V
3
4
LIGHT CONVERSION = 4V/uW
TYPICAL NOISE LEVEL =
1mVPP (200pW LIGHT)
CATHODE
4.7uF
C5
100K
R6
100
R8
BACK SURFACE
R7
1M
PIN
L2
ANODE
100 SQ mm ACTIVE AREA
2H
CURRENT TO VOLTS
4.7uF
C6
TANT
X4 AMP
Q = 2
33
R9
METAL SHIELD
DAVID JOHNSON AND ASSOCIATES
OPTICAL THROUGH-THE-AIR RECEIVER
40KHz LIGHT DETECTOR
40KHz MODULATED LIGHT RECEIVER
DRAWN BY: DAVE JOHNSON
40KRVR1.DSN
Friday, March 12, 1999

Figure 6p

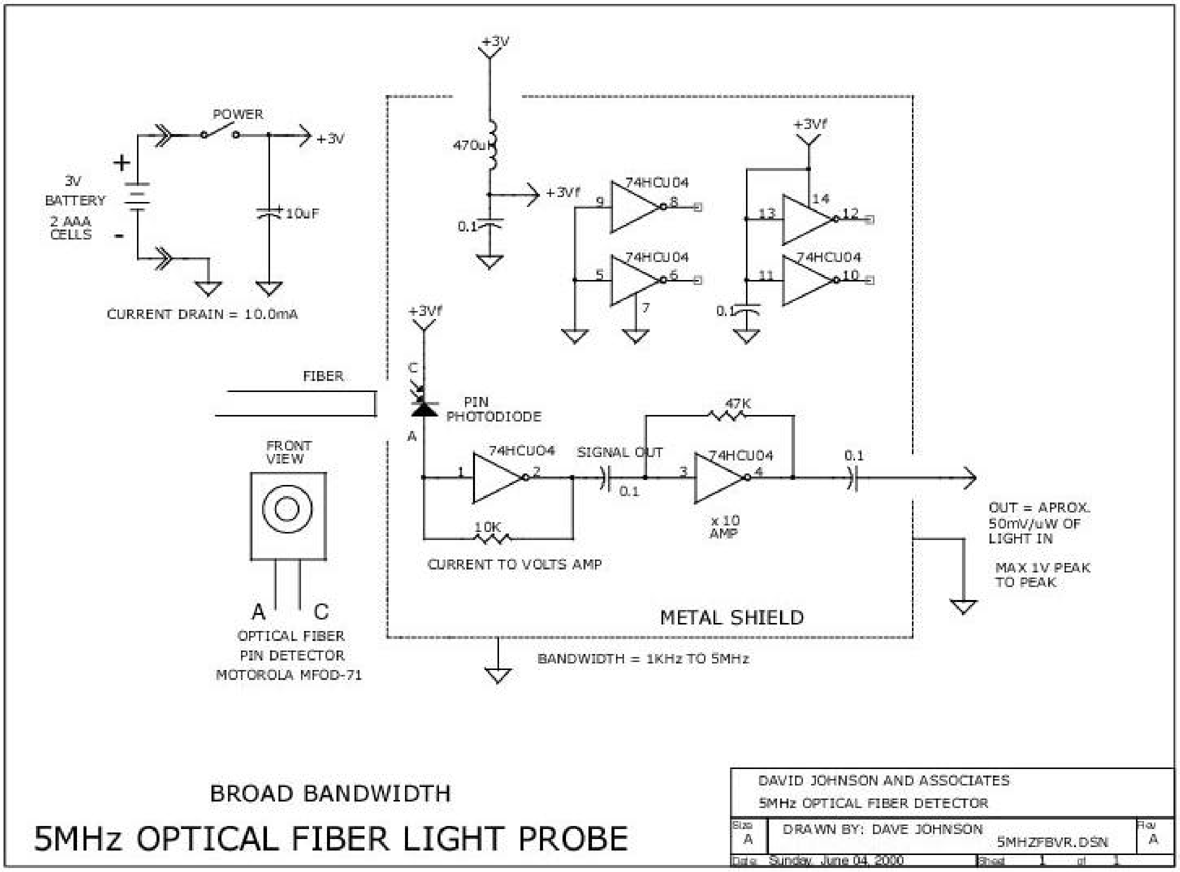
+3V
POWER
+3V
3V
BATTERY
2 AAA
CELLS
10uF
CURRENT DRAIN = 10.0mA
470uH
+3Vf
0.1
74HCU04
+3Vf
FIBER
C
PIN
PHOTODIODE
A
FRONT
VIEW
74HCUO4
SIGNAL OUT
74HCU04
47K
0.1
10K
x 10
AMP
CURRENT TO VOLTS AMP
OUT = APROX.
50mV/uW OF
LIGHT IN
MAX 1V PEAK
TO PEAK
A
C
OPTICAL FIBER
PIN DETECTOR
MOTOROLA MFOD-71
METAL SHIELD
BANDWIDTH = 1KHz TO 5MHz
BROAD BANDWIDTH
5MHz OPTICAL FIBER LIGHT PROBE
DAVID JOHNSON AND ASSOCIATES
5MHz OPTICAL FIBER DETECTOR
DRAWN BY: DAVE JOHNSON
5MHZFBVR.DSN
Sunday, June 04, 2000

Figure 6o

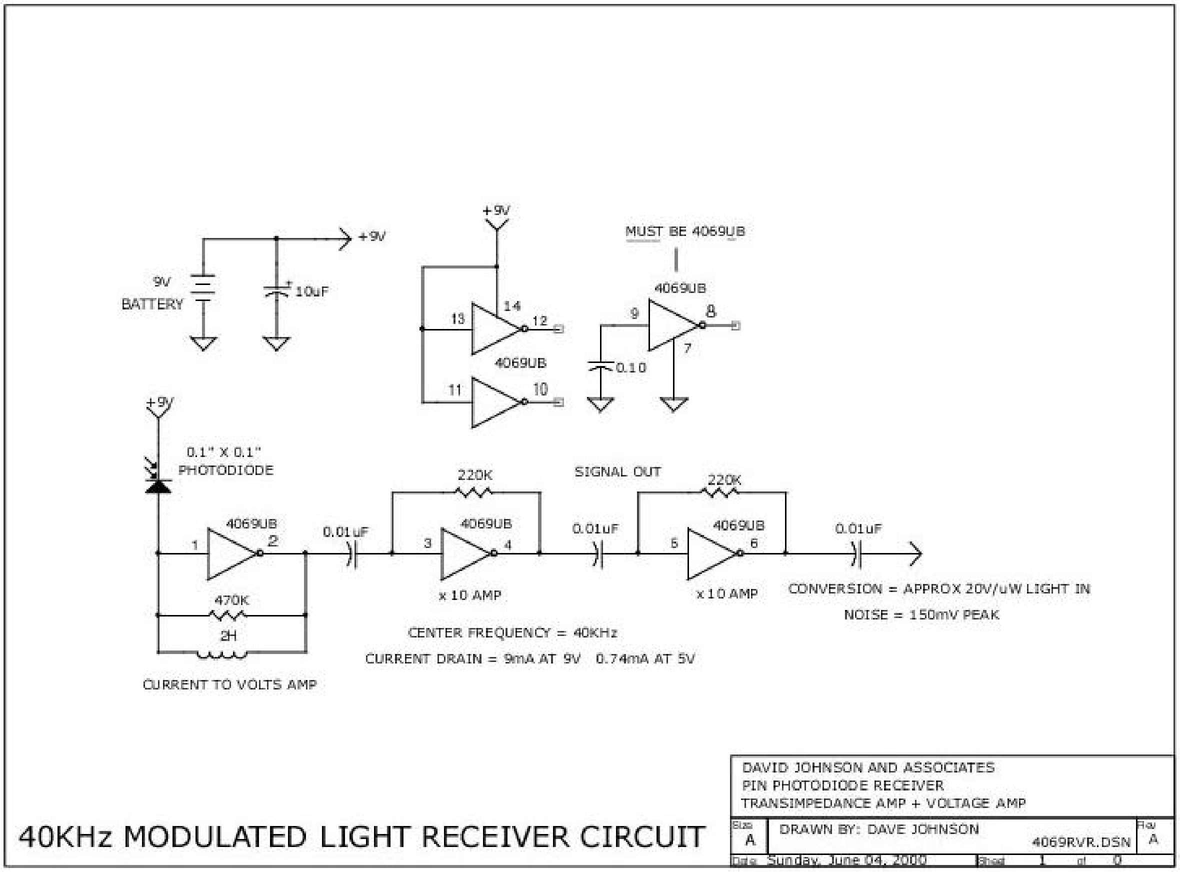
+9V
9V
BATTERY
10uF
MUST BE 4069UB
4069UB
14
13
12
11
10
9
8
7
0.10
+9V
0.1" X 0.1"
PHOTODIODE
220K
SIGNAL OUT
220K
4069UB
4069UB
4069UB
1
2
3
4
5
6
0.01uF
0.01uF
0.01uF
x 10 AMP
x 10 AMP
470K
2H
CONVERSION = APPROX 20V/uW LIGHT IN
NOISE = 150mV PEAK
CENTER FREQUENCY = 40KHz
CURRENT DRAIN = 9mA AT 9V 0.74mA AT 5V
CURRENT TO VOLTS AMP
DAVID JOHNSON AND ASSOCIATES
PIN PHOTODIODE RECEIVER
TRANSIMPEDANCE AMP + VOLTAGE AMP
40KHz MODULATED LIGHT RECEIVER CIRCUIT
A
DRAWN BY: DAVE JOHNSON
4069RVR.DSN
A
Sunday, June 04, 2000

Figure 6n

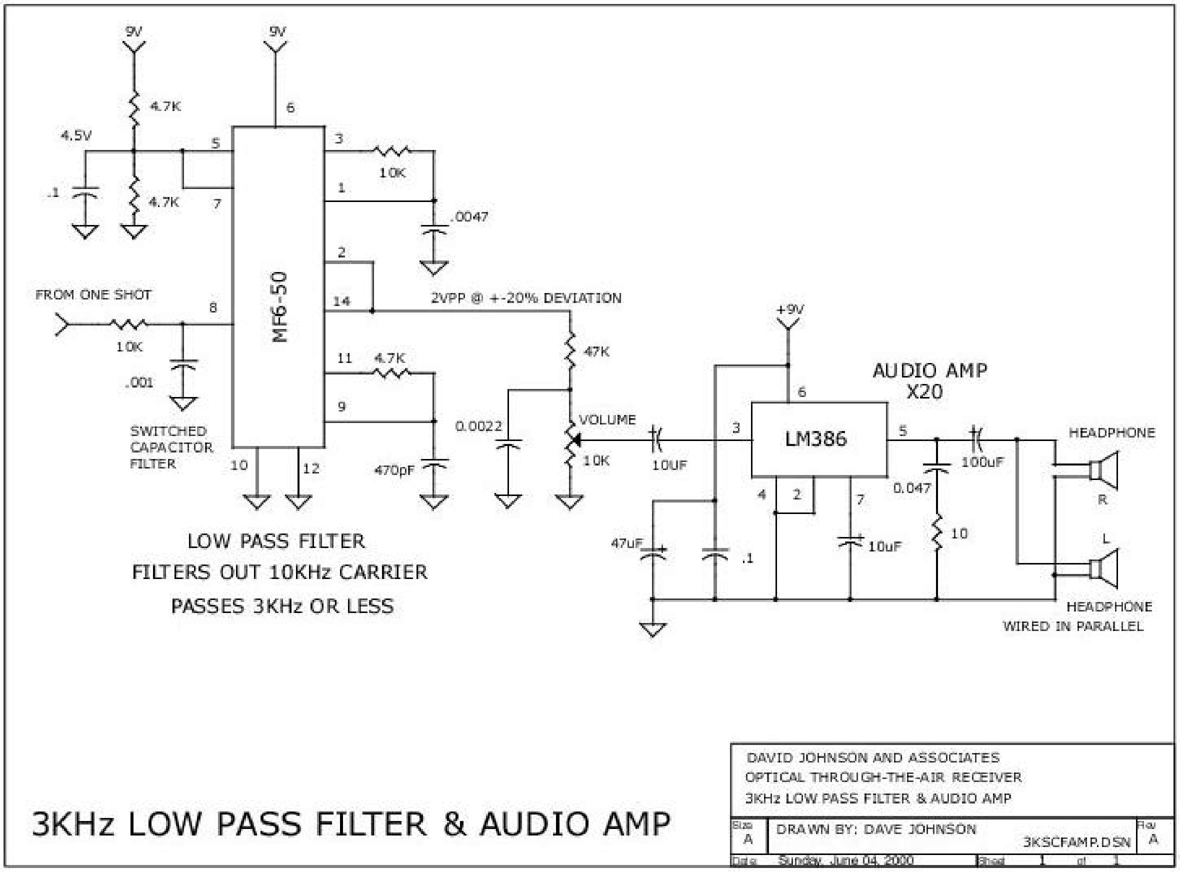
9V
9V
4.7K
6
4.5V
5
3
10K
.1
4.7K
7
1
.0047
2
FROM ONE SHOT
8
MF6-50
14
2VPP @ +-20% DEVIATION
+9V
10K
47K
.001
11
4.7K
AUDIO AMP
X20
6
9
SWITCHED
CAPACITOR
FILTER
0.0022
VOLUME
3
LM386
5
HEADPHONE
10
12
470pF
10K
10UF
100uF
0.047
4
2
7
R
10
L
47uF
.1
10uF
LOW PASS FILTER
FILTERS OUT 10KHz CARRIER
PASSES 3KHz OR LESS
HEADPHONE
WIRED IN PARALLEL
DAVID JOHNSON AND ASSOCIATES
OPTICAL THROUGH-THE-AIR RECEIVER
3KHz LOW PASS FILTER & AUDIO AMP
3KHz LOW PASS FILTER & AUDIO AMP
Size
A
DRAWN BY: DAVE JOHNSON
3KSCFAMP.DSN
Rev
A
Date
Sunday, June 04, 2000
Sheet
1
of
1

Figure 6l

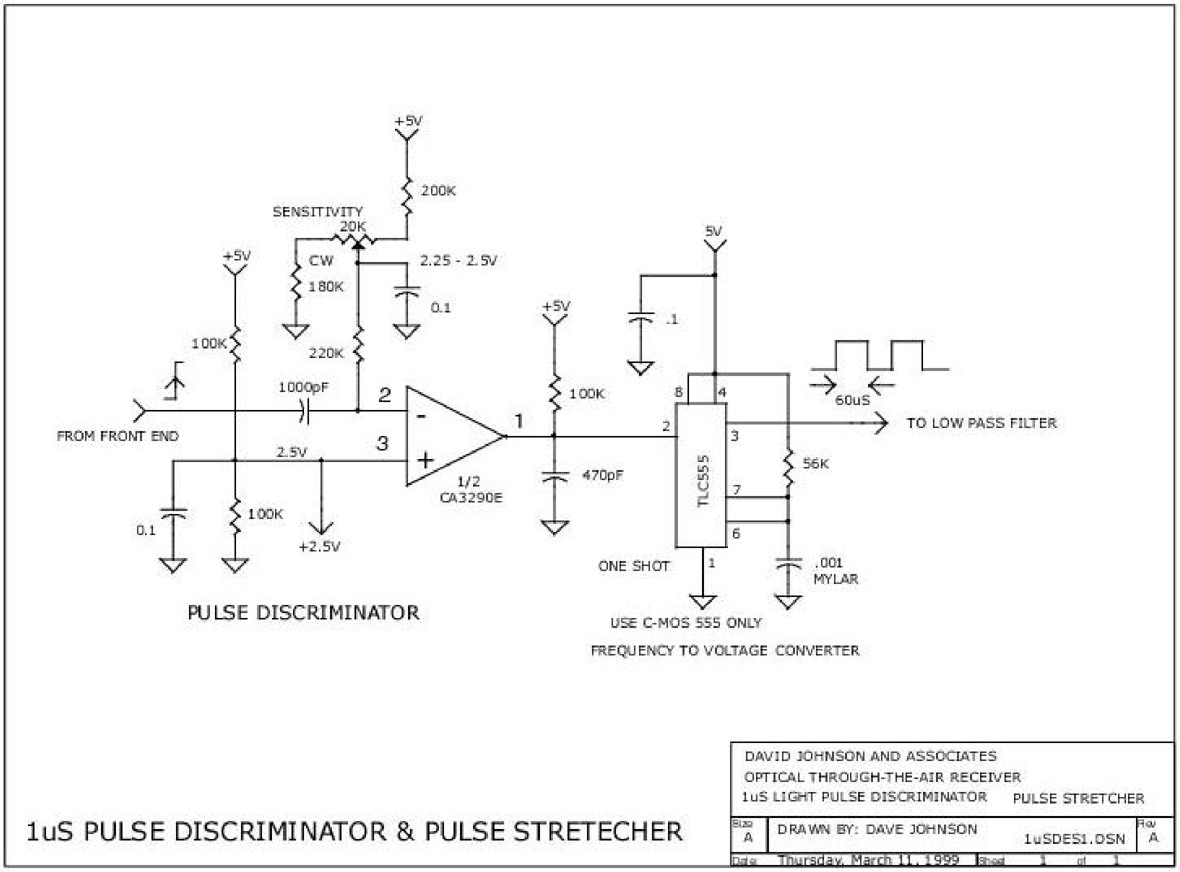
+5V
200K
SENSITIVITY
20K
CW
180K
2.25 - 2.5V
0.1
+5V
100K
220K
1000pF
2
3
FROM FRONT END
2.5V
0.1
100K
+2.5V
1
1/2
CA3290E
+5V
100K
470pF
5V
.1
8
4
2
3
7
6
1
TLC555
56K
60uS
TO LOW PASS FILTER
.001
MYLAR
ONE SHOT
USE C-MOS 555 ONLY
FREQUENCY TO VOLTAGE CONVERTER
PULSE DISCRIMINATOR
DAVID JOHNSON AND ASSOCIATES
OPTICAL THROUGH-THE-AIR RECEIVER
1uS LIGHT PULSE DISCRIMINATOR
PULSE STRETCHER
1uS PULSE DISCRIMINATOR & PULSE STRETECHER
A
DRAWN BY: DAVE JOHNSON
1uSDES1.DSN
A
Thursday, March 11, 1999
1
of
1

Figure 6k

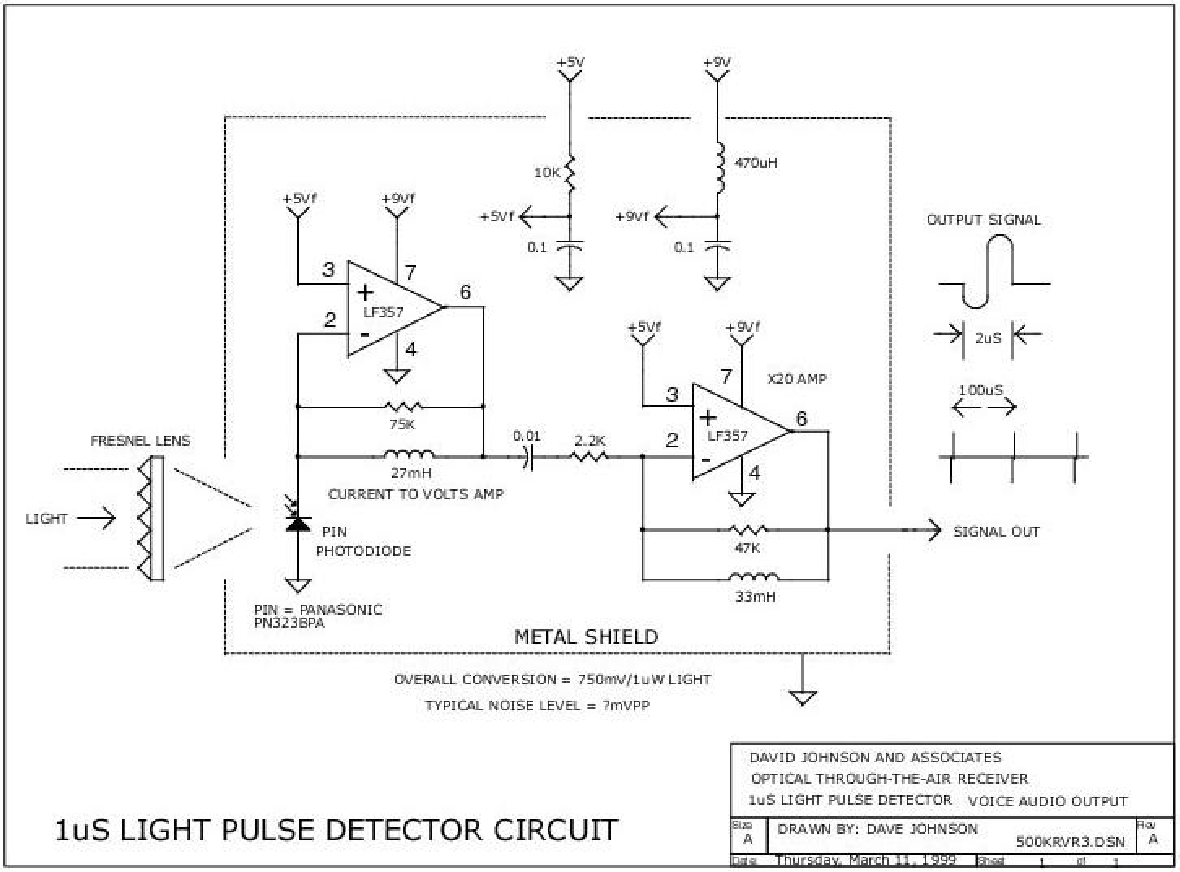
+5V
+9V
10K
470uH
+5Vf
+9Vf
+5Vf
+9Vf
0.1
0.1
OUTPUT SIGNAL
3
7
6
LF357
2
4
2uS
+5Vf
+9Vf
7
X20 AMP
100uS
3
6
LF357
2
4
75K
FRESNEL LENS
0.01
2.2K
27mH
CURRENT TO VOLTS AMP
LIGHT
PIN
PHOTODIODE
47K
SIGNAL OUT
33mH
PIN = PANASONIC
PN323BPA
METAL SHIELD
OVERALL CONVERSION = 750mV/1uW LIGHT
TYPICAL NOISE LEVEL = ?mVPP
DAVID JOHNSON AND ASSOCIATES
OPTICAL THROUGH-THE-AIR RECEIVER
1uS LIGHT PULSE DETECTOR VOICE AUDIO OUTPUT
1uS LIGHT PULSE DETECTOR CIRCUIT
A
DRAWN BY: DAVE JOHNSON
500KRVR3.DSN
A
Thursday, March 11, 1999
1
1

Figure 6j

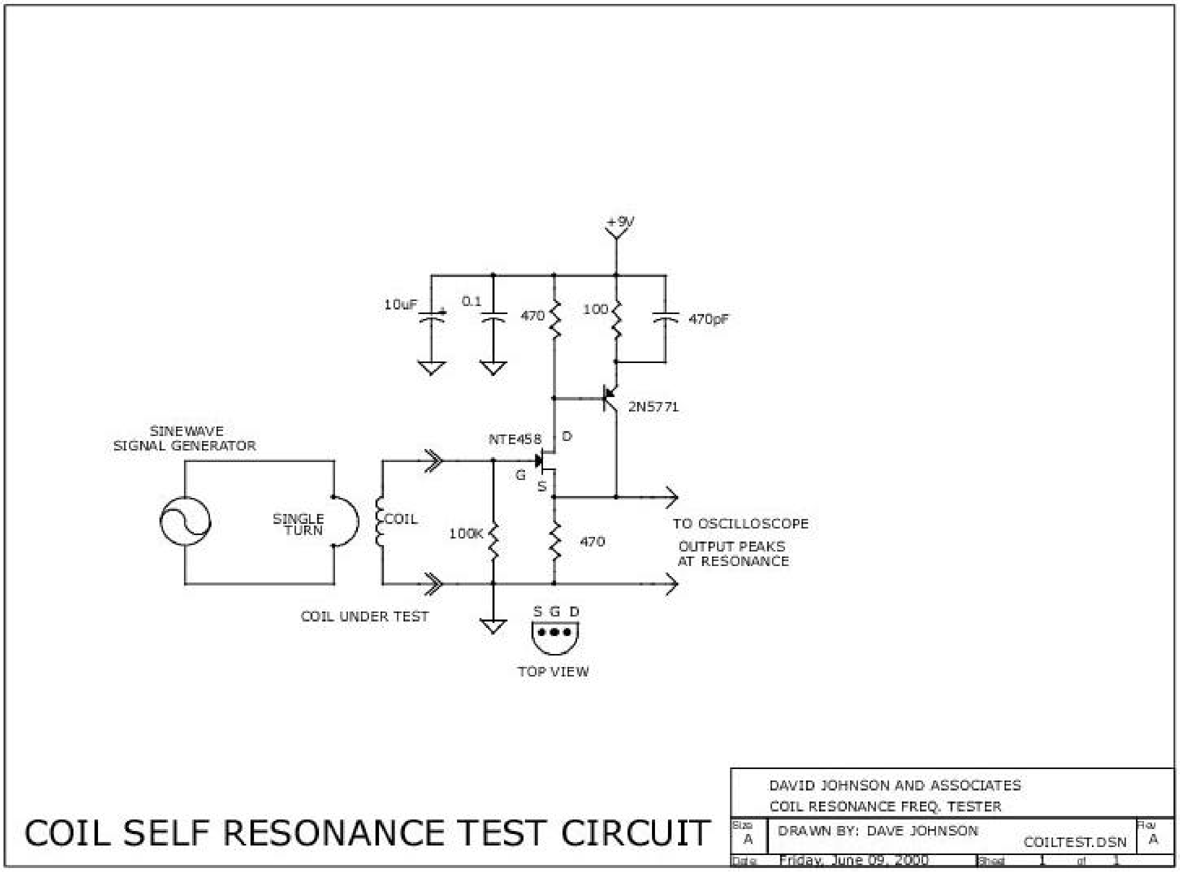
+9V
10uF
0.1
470
100
470pF
2N5771
SINEWAVE
SIGNAL GENERATOR
NTE458
D
G
S
SINGLE
TURN
COIL
100K
470
TO OSCILLOSCOPE
OUTPUT PEAKS
AT RESONANCE
COIL UNDER TEST
S G D
TOP VIEW
COIL SELF RESONANCE TEST CIRCUIT
DAVID JOHNSON AND ASSOCIATES
COIL RESONANCE FREQ. TESTER
A
DRAWN BY: DAVE JOHNSON
COILTEST.DSN
A
Friday, June 09, 2000

Figure 6e

microwatt. With the values shown, the circuit will work with light modulation frequencies between 1KHz and 200KHz.

A similar circuit is shown in ***figure 6o on page 57***. It uses a much faster 74HCU04 device instead of the CD4069UB. The circuit should be operated from a 3v supply. For real flexibility, I have shown how a Motorola MFOD-71 optical fiber photodiode module can be used. The circuit's 2MHz bandwidth is great when monitoring light pulses with fast edges. A section of inexpensive plastic optical fiber can be attached to the detector and used as a light probe to inspect the output from various modulated light sources. Keep in mind, that since both broad band circuits do not use an inductor in the feedback circuit, they should only be operated in low ambient light conditions.

A very sensitive light receiver circuit, designed for detecting the 40KHz signal used by many optical remote control devices, is shown in ***figure 6p on page 58.*** The circuit shown uses a one inch plastic lens in conjunction with a large 10mm X 10mm photodiode. With the values chosen, the circuit will detect light from a typical optical remote from several hundred feet away. If the remote control circuit also used a small lens the separation distance could extend to several miles.

One of the most difficult problems to overcome in an optical through the air communications system is ambient light. Any stray sunlight or bright background light that is collected by the receiver optics and focused onto the light detector will produce a large steady state DC level through the detector circuit. Although much of the DC is ignored with the use of an inductive feedback amplifier method in the front-end circuit, the large DC component in the light detector will produce some unwanted broadband noise. The noise is very much like the background static you may hear on an AM radio when tuning the dial between stations. As discussed in the section on light detectors, the amount of noise produced by the detector is predictable.

LIGHT DETECTOR NOISE

$$Id = \sqrt{(3.2 \times 10^{-19})(Bw)(E)(Ia)}$$

Id = RMS NOISE CURRENT FOR DETECTOR IN AMPS
Bw = RECEIVER BANDWIDTH IN HERTZ
E = DETECTOR CONVERSION EFFICIENCY (TYP 0.5)
Ia = DETECTOR DC CURRENT FROM AMBIENT LIGHT IN AMPS

NOTE: TYPICAL PEAK NOISE IS APPROX. 5X THE RMS

Figure 6m

The equation shown in ***figure 6m*** describes how the detector noise varies with ambient light. The relationship follows a square root function. That means if the ambient light level increases by a factor of four, the noise produced at the detector only doubles. This characteristic both helps and hurts a light receiver circuit, depending on whether the system is being used during the light of day or during the dark of night. The equation predicts that for high ambient daytime conditions, you will have to dramatically reduce the amount of ambient light striking the detector in order to see an significant reduction in the amount of noise produced at the detector circuit. The equation also describes that under dark nighttime conditions, the stray light has to dramatically increase in order to produce a sizable elevation in noise. If the system must work during both day and night, it will have to contend with the worst daytime noise conditions. Conversely, some light receivers could take advantage of the low stray light conditions found at night and produce a communications system with a much longer range than would be otherwise possible if it were used during daylight.

As mentioned above, inserting an optical filter between the lens and the light detector can reduce the effects of ambient light. But, as shown by the noise equation, the amount of light hitting the detector needs to be dramatically reduced to produce a sizable reduction in the induced noise. Since most sunlight contains a sizable amount of infrared light, such filters do not reduce the noise level very much. However, very narrow band filters that can be selected to match the wavelength of a laser diode light source, are effective in reducing ambient light and therefore noise.

Other Receiver Circuits

The circuits described above were designed for a voice audio communications system that received narrow 1uS light pulses. An experimenter may wish to use other modulation frequencies. In addition, untuned broad band receiver circuits are handy when monitoring modulated light signals where the frequency is not known. I have included some additional circuits below that you may find helpful.

A very simple and inexpensive broad band light receiver circuit is shown in ***figure 6n on page 56***. The circuit uses a CD4069UB C-MOS logic integrated circuit. Make sure to use the unbuffered UB version of this popular device. The first section of the circuit performs the current to voltage conversion. The other section provides voltage gain. The overall conversion is about 2 volts per

Once the signal has been sufficiently amplified and filtered, it often needs to be separated completely from any background noise. Since most systems use pulse frequency modulation techniques to transmit the information, the most common method to separate the signal from noise is with the use of a voltage comparator. The comparator can produce an output signal that is thousands of times higher in amplitude than the input signal. As an example, a properly designed comparator circuit can produce a 5 volt peak to peak TTL logic output signal from a input of only a few millivolts.

But, to insure that the comparator can faithfully extract the signal of interest, the signal must be greater in amplitude than any noise by a sizeable margin. For most applications, I recommend that the signal to noise ratio exceed a factor of at least 10:1 (20db). Then, with a properly designed comparator circuit, the comparator output would change state (toggle) only when a signal is present and will not be effected by noise.

A complete signal discriminator circuit is shown in ***figure 6k on page 54.*** The circuit is designed so a positive input pulse needs to exceed a threshold voltage before the comparator produces a negative output pulse. A variable resistor network allows the threshold voltage to be adjustable. The adjustment thereby provides a means to set the sensitivity of the circuit. The adjustment should be made under the worst case bright background conditions so the noise produced by the bright background light does not toggle the comparator.

Frequency to Voltage Converters

If the light pulses being transmitted are frequency modulated to carry the information, then the reverse must be done to restore the original information. The pulse frequency must therefore be converted back into the original amplitude changing signal. A simple but very effective frequency to voltage converter circuit is shown in ***figure 6k on page 54***. Each pulse from the pulse discriminator circuit is converted into a well defined logic level pulse that lasts for a specific time. As the frequency increases and decreases, the time between the pulses will change. The changing frequency will therefore cause the average voltage level of the signal produced by the converter to change by the same proportion. To remove the unwanted carrier frequency from the desired modulation frequency, the output of the converter must be filtered.

Modulation Frequency Filters

A complete filter circuit is shown in ***figure 6l on page 55.*** The circuit uses a switched capacitor filter (SCF) integrated circuit from National Semiconductor. With the values chosen, the circuit removes the majority of a 10KHz carrier signal, leaving the wanted voice audio frequencies. The filter's cutoff frequency is set at about 3KHz that is the minimum upper frequency needed for voice audio.

Audio Power Amplifiers

The final circuit needed to complete a voice grade light pulse receiver is an audio power amplifier. The circuit shown in ***figure 6l on page 55*** uses a single inexpensive LM386 IC. The circuit is designed to drive a pair of audio headphones. The variable resistor shown is used to adjust the audio volume. Since the voice audio system described above does not transmit stereo audio, the left and right headphones are wired in parallel so both ears receive the same audio signal.

Light Receiver Noise Considerations

Figure 6h* and *6i illustrate what happens in a circuit with a low Q and high Q when processing single pulses. If higher duty cycle pulse trains are being transmitted, higher Qs can be used. In near 50% duty cycle transmission systems, Qs in excess of 50 are possible with a careful design. Table *6f* lists the typical self-resonant frequency of some inductors. If you don't know the self-resonant frequency of a coil you can use the schematic shown in ***figure 6e on page 52*** to measure it.

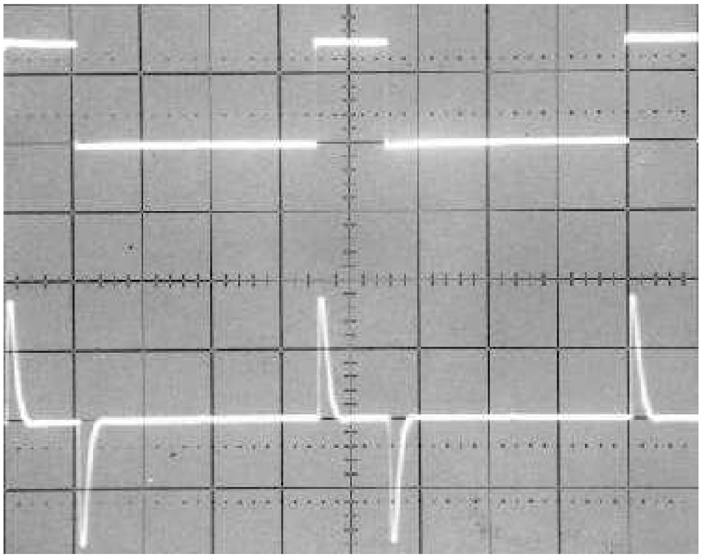

Figure 6h

In low duty cycle light pulse applications, the inductor value should be chosen based on the width of the light pulse being sent by the transmitter. The self-resonant period (1/frequency) of the coil should equal 2W, where W is the width of the light pulse. Since the circuit layout, the amplifier circuit and the PIN diode will all add to the overall circuit capacitance, some experimentation will be necessary to determine the best inductor value for the particular application. The equation 2pFL should be used to calculate the value of the resistor wired in parallel to the inductor to limit the Q to 1.

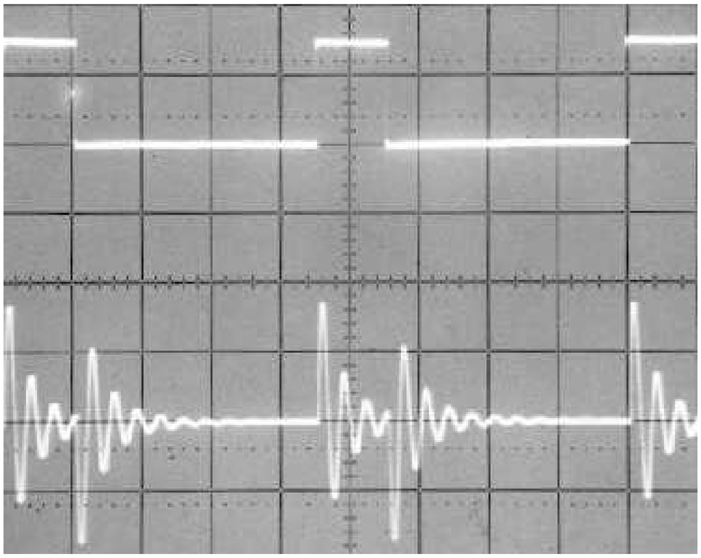

Figure 6i

Figure 6j on page 53 is an example of a complete transimpedance amplifier circuit with inductive feedback. The amplifier circuit shown in ***figure 6j on page 53*** has a light power to voltage conversion of about 23 millivolts per milliwatt (assuming 50% PIN conversion) when used with 1 microsecond light pulses. Such an amplifier should be able to detect light pulses as weak as one nanowatt during dark nighttime conditions.

Post Signal Amplifier

As discussed above, the transimpedance amplifier converts the PIN current to a voltage. However, it may be too much to expect one amplifier stage to boost the signal of interest to a useful level. Typically, one or more voltage amplifier stages after the front end circuit are needed. Often the post amplifiers will include some additional signal filters so only the desired signals are amplified, rejecting more of the undesired noise. A general purpose post amplifier is shown in ***figure 6j on page 53***.

The circuit uses a quality operational amplifier in conjunction with some filter circuits designed to process light pulses lasting about 1 micro second. The circuit boosts the signal by a factor of X20.

Signal Pulse Discriminators

Typical Inductor Self Resonance Frequencies		
Inductance	**Frequency**	**Reactance at Res. Frequency**
4H	200KHz	500K Ohms
100mH	200KHz	100K Ohms
47mH	250KHz	75K Ohms
27mH	300KHz	50K Ohms
15mH	500HKz	50K Ohms
10mH	700KHz	40K Ohms
4.7mH	800KHz	22K Ohms
2.2mH	1MHz	14K Ohms
1mH	2HMz	12K Ohms
470uH	3MHz	9K Ohms
100uH	7MHz	4.4K Ohms

Figure 6f

Transimpedance Amplifier Detector Circuit with Limited Q

The use of a LC tuned circuit in a transimpedance amplifier circuit does improve the current to voltage conversion and does reject much of the signals associated with ambient light. But, high Q circuits are prone to unwanted oscillations. As shown in ***figure 6g***, to keep the circuit from misbehaving, a resistor should be wired in parallel with the inductor. The effect of the resistor is to lower the circuit's Q. For pulse stream applications with low duty cycles (short pulses with lots of time between pulses), it is best to keep the Q near 1. A Q of one exists when the reactance of the coil is equal to the parallel resistance at the desired frequency. If higher Qs were used, with low duty cycle pulse streams, the transimpedance amplifier would produce excessive ringing with each pulse and would be prone to self-oscillation.

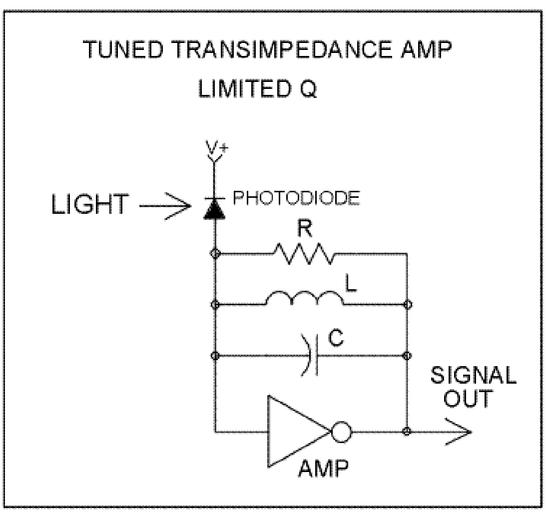

Figure 6g

Transimpedance Amplifier Detector Circuit With Inductor Feedback

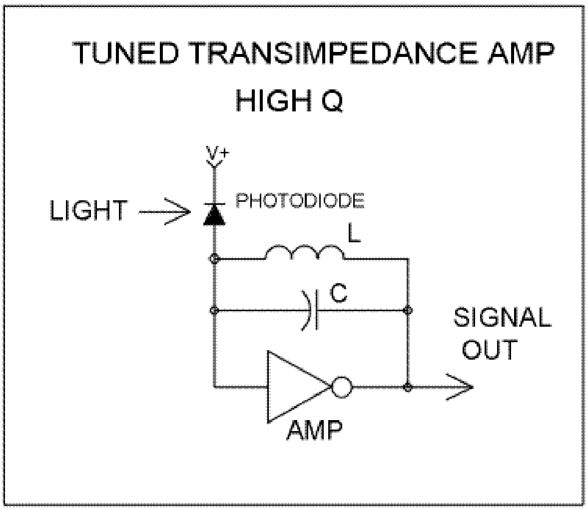

Figure 6c

A dramatic improvement of the transimpedance amplifier with a resistor feedback load is shown in **figure *6c*.** This technique is borrowed from similar circuits used in radio receivers. The circuit replaces the resistor with an inductor. A student in electronics may remember that an inductor will pass DC unaffected but will exhibit a resistance effect or reactance to AC signals. The higher the frequency of the AC signals the higher the reactance. This reactance circuit is exactly what is needed to help extract the sometimes small modulated AC light signal from the large DC component caused by unmodulated ambient light. DC signals from ambient light will yield a low current to voltage conversion while high frequency AC signals will experience a high current to voltage conversion. With the right circuit, an AC vs. DC conversion ratio of several million is possible. Such techniques are used throughout radio receiver circuits to process weak signals.

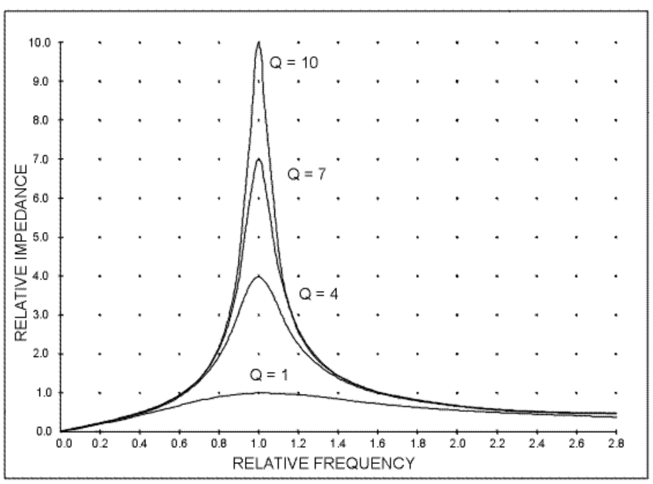

Figure 6d

In addition, as the Q increases so does the impedance of the LC circuit. Such high Q circuits can also be used in a transimpedance amplifier designed for optical communications. To obtain the highest possible overall impedance, the inductance value should be as large as possible and the capacitance should be as small as possible. Since every inductor contains some finite parallel capacitance within its assembly, the highest practical impedance occurs when only the capacitance associated with the inductor assembly is used to form the LC network. In radio, connecting a capacitor in parallel with the inductor often produces high impedances and allowing the LC tuned circuit to resonant at a specific frequency. Such a circuit can be very frequency selective and can yield impedances of several mega ohms. The degree of rejection to frequencies outside the center resonant frequency is defined as the "Q" of the circuit. As **figure *6d*** depicts, a high Q will produce a narrower acceptance band of frequencies than lower Q circuits.

You can calculate the equivalent parallel capacitance of an inductor based on the published "self-resonance" frequency or you can use a simple test circuit to actually measure the resonance frequency **(*see figure 6e on page 54*)** of a coil. ***Figure 6f*** lists the characteristics of some typical coils.

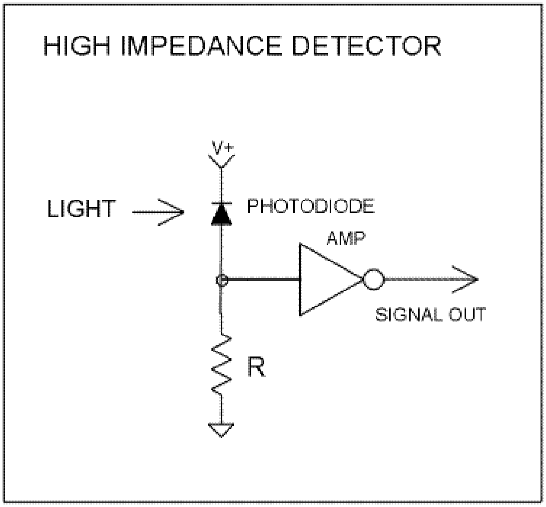

Figure 6a

leakage current, approaches the voltage used to bias the PIN device. To prevent saturation, the PIN must maintain a bias voltage of at least a few volts.

Consider the following example. Under certain bright background conditions a PIN photodiode leakage current of a few milliamps may be possible. If a 12v bias voltage were used, the detector resistance would have to be less than 10,000 ohms to avoid saturation. With a 10K resistor, the conversion would then be about 10 millivolts for each microamp of PIN leakage current. But, to extract the weak signal of interest that may be a million times weaker than the ambient light level, the resistance should to be as high as possible to get the best current to voltage conversion. These two needs conflict with each other in the high impedance technique and will always yield a less than desirable compromise.

In addition to a low current to voltage conversion, there is also a frequency response penalty paid when using a simple high impedance detector circuit. The capacitance of the PIN diode and the circuit wiring capacitance all tend to act as frequency filters and will cause the circuit to have a lower impedance when used with the high frequencies associated with light pulses. Furthermore, the high impedance technique also does not discriminate between low or high frequency light signals. Flickering streetlights, lightning flashes or even reflections off distant car windshields could be picked up along with the weak signal of interest. The high impedance circuit is therefore not recommended for long-range optical communications.

Transimpedance Amplifier Detector Circuit With Resistor Feedback

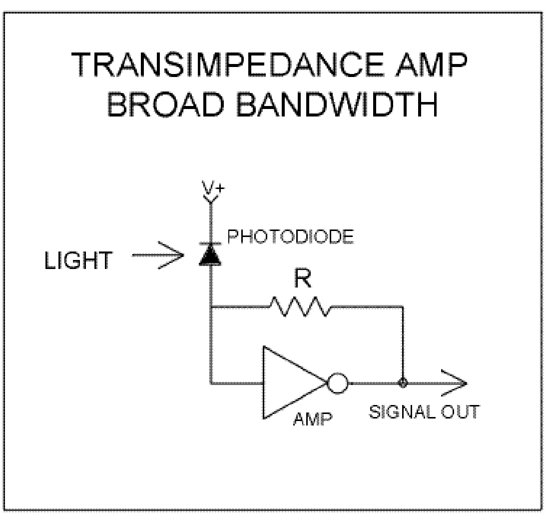

Figure 6b

An improvement over the high impedance method is the "transimpedance amplifier" as shown in **figure *6b*.** The resistor that converts the current to a voltage is connected from the output to the input of an inverting amplifier. The amplifier acts as a buffer and produces an output voltage proportional to the photodiode current. The most important improvement the transimpedance amplifier has over the simple high impedance circuit is its canceling effect of the circuit wiring and diode capacitance. The effective lower capacitance allows the circuit to work at much higher frequencies. However, as in the high impedance method, the circuit still uses a fixed resistor to convert the current to a voltage and is thus prone to saturation and interference from ambient light.

biased. In the reversed biased mode it becomes a diode that leaks current in response to the light striking it. The current is directly proportional to the incident light power level (light intensity).

When detecting light at its peak spectrum response wavelength of 900 nanometers, the silicon PIN photodiode will leak about 0.5 micro amps of current for each microwatt of light striking it. This relationship is independent to the size of the detector. The PIN photodiode size should be chosen based on the required frequency response and the desired acceptance angle with the lens being used. Large PIN photodiodes will have slower response times than smaller devices. For example, 1 cm X 1 cm diodes should not be used for modulation frequencies beyond 200KHz, while 2.5 mm X 2.5 mm diodes will work beyond 50MHz. If a long range is desired, the largest photodiode possible that will handle the modulation frequency should be used.

Stray Light Filters

Some systems can benefit from the placement of an optical filter between the lens and the photodiode. The filter can reduce the effects of sunlight and some stray light from distant street lamps. Filters can be especially effective if the light detector is going to be processing light from a diode laser. Since laser light has a very narrow bandwidth, an optical band pass filter that perfectly matches the laser light can make a light receiver nearly blind to stray sunlight.

If light emitting diode light sources are used, optical filters with a much broader bandwidth are needed. Such a filter may be needed for some situations where man-made light is severe. Many electronically controlled fluorescent and metal vapor lamps can produce unwanted modulated light that could interfere with the light from the distant transmitter.

But, in all but a few rare exceptions, band pass filters produce few overall improvements if the correct detector circuit is used. Since no optical filter is perfectly transparent, the noise reduction benefits of the filter usually do not out weigh the loss of light through the filter. Also, if the detector is going to process mostly visible light, no optical filter should be used.

Current to Voltage Converter Circuits

The current from the PIN detector is usually converted to a voltage before the signal is amplified. The current to voltage converter is perhaps the most important section of any optical receiver circuit. An improperly designed circuit will often suffer from excessive noise associated with ambient light focused onto the detector. Many published magazine circuits and even many commercially made optical communications systems fall short of achievable goals from poorly designed front-end circuits. Many of these circuits are greatly influenced by ambient light and therefore suffer from poor sensitivity and shorter operating ranges when used in bright light conditions. To get the most from your optical through-the-air system you need to use the right front-end circuit.

High Impedance Detector Circuit

One method that is often shown in many published circuits, to convert the leakage current into a voltage, is illustrated in *figure 6a*. This simple "high impedance" technique uses a resistor to develop a voltage proportional to the light detector current. However, the circuit suffers from several weaknesses. If the resistance of the high impedance circuit is too high, the leakage current, caused by ambient light, could saturate the PIN diode, preventing the modulated signal from ever being detected. Saturation occurs when the voltage drop across the resistor, from the photodiode

Chapter Six
OPTICAL RECEIVER CIRCUITS

The overall task of the optical receiver is to extract the information that has been placed on the modulated light carrier by the distant transmitter and restores the information to its original form. The typical through-the-air communications receiver can be broken down into five separate sections. These are: light collector (lens), light detector (PIN), current to voltage converter, signal amplifier and pulse discriminator. There may also be additional circuits depending on the kind of the signal being received. As an example, a receiver that is extracting voice information will need a frequency to voltage converter and an audio amplifier to reproduce the original voice signal. Computer data receivers will also need some decoding circuits that would configure the transmitted serial data bits into 8 bit words. However, this section will concentrate on the circuits needed for processing voice information. Volume II of this book will contain additional circuits for digital data receivers.

Light Collector

For long-range applications it is essential to collect the weak modulated light from the distant transmitter with a glass or plastic lens and focus it onto a silicon PIN photodiode. Although mirrors could also be used to collect the light, glass or plastic lenses are easier to use and cost less. Plastic lenses measuring from a fraction of an inch to six inches are available. For a system that demands a large lens, the flat "Fresnel" lens is much less expensive than a solid lens. Forming special concentric bumps in a clear plastic sheet makes Fresnel lenses. The bumps bend the light just as a conventional thick lens would. Fresnel lenses are available with diameters of several feet.

For certain short-range applications it may also be possible to use a naked light detector without any lens. Distances up to several hundred feet are possible with systems that don't rely on lenses at either the transmitter or the receiver. Lens-less systems are especially useful when very wide acceptance angles are required. Many cordless IR stereo headsets use two or more naked detectors to provide acceptance angles approaching 360 degrees.

The lens chosen should be as large as possible but not too large. A lens that is too large can produce a half angle acceptance angle that is too small. Acceptance angles less than about 0.3 degrees will result in alignment difficulties. Building sway and atmospheric disturbances can cause signal disruption with narrow acceptance angles. A rough rule-of-thumb might be that the lens diameter should not be more than 100 times larger than diameter of the active area of the PIN detector. Also, the receiver should never be positioned so sunlight could be focused onto the light detector. Even a brief instant of focused sunlight will destroy the sensor. A north/south alignment for the transmitter and the receiver will usually prevent an optical system from going blind from focused sunlight.

Light Detector

As discussed in the section on light detectors, the silicon PIN photodiode is the recommended detector for most all through-the-air communications. Such a detector works best when reversed