REMOTE CONTROL RANGE EXTENDERS

By Tommy N. Tyler last revised 5 March 2005

1. BACKGROUND. Most infrared remote controls do a pretty good job of transmitting their signals over distances sufficient for a home theater, even though the usable range varies widely among different units. There are many factors that affect the range, including the quality and number of IR LED's, how hard they are driven (circuit design), the condition of the batteries, alignment with target, . . . the list goes on and on. Sooner or later many of us are confronted with a situation where a remote doesn't perform, for reasons that fall into one of two distinct categories -- "too far away" or "out of sight". The first category refers to situations where the remote can see the target, it just can't quite reach it. The second category refers to situations where the target is in another room, or behind a cabinet door.

Both of these problems have been addressed in various ways by a number of commercial products, generally referred to as "Range Extenders". One way is by transmitting a remote's signal from one place to another through dedicated wires, or superimposed on video cables. Another way is by using UHF radio links, such as the familiar cones and pyramids sold under various brand names like RCA, Panasonic, Terk, and Powermid. A third type of product is a "repeater" that picks up an infrared signal, amplifies it, and retransmits it at increased power. Probably the best of these is the Hot Link Pro by Microsmith, Inc. (www.hot-link.com). They refer to it as a "remote control booster". The unit has a very sensitive infrared sensor that can pick up signals from about twice as far away as the average TV can. Whatever it receives it amplifies and retransmits through a group of six LED's, each on an individual 7-ft. cable. A common application of Hot Link Pro is with its sensor element installed where it can "see" the remote, and its LED's stuck on various controlled units in a closet or cabinet. Even though my theater equipment is in plain view, I use the Hot Link Pro for the benefit of its sensitive receiver. It always picks up a remote signal without careful aiming, even when batteries are low. I would put one in every room if it weren't for the $100 price tag.

This article deals primarily with UHF type range extenders, and specifically how to use them with external LED emitters. There's also a section on how to make your own stick-on emitters.

2. WHY REMOTE SIGNALS ARE SOMETIMES A DOLLAR SHORT. The strength of a remote's IR signal is determined by many factors, all interrelated. You may wonder why all remotes don't use two LED's, or even three. Other than obvious cost considerations, the available battery voltage is the main reason. In the simplest circuit configuration for driving an infrared LED there are three components connected in series, each demanding a chunk of the available voltage. First, there's the LED itself, which typically needs at least 1.5 volts. Next, there's a small resistor to limit and stabilize the LED current, and it needs to drop at least 1.0 volts to do its job effectively. Finally, the transistor that turns the LED on and off is not a perfect switch, and can also have a saturated voltage drop of as much as 0.5 volts or more. Add those up and you can see that a 3-volt remote just doesn't supply enough voltage for two LEDs in series. Of course you can add a second LED in parallel with the first but this entails other problems, not the least of which is doubling the current through the driver transistor. The only 3-volt remote I've ever seen that used two LED's in parallel was a Panasonic ShowStopper remote, although there may be others. With 6-volt remotes there's plenty of voltage for driving two LED's in series, but three would eat up 4.5 volts for the LED's alone, with not enough left for a series resistor and transistor under low battery conditions.

When you can't add another LED, you try to get more light out of the one you have. The amount of infrared light emitted from an LED is almost directly proportional to it's current, up to the point where the LED overheats. The power in an LED is equal to its voltage drop multiplied by the current through it. Most of that power generates heat, and only a small percentage is converted to actual light output. If a remote is pulsing its LED at 1/3 amp with a 50% duty cycle, the LED is dissipating (1.5V x 0.33A x 50%), or about 1/4 watt. Take a look at the tiny chip lying in the metal cup inside an LED and try to imagine that dissipating the same amount of heat as the body of a 1/4 watt resistor, and you'll appreciate the need to limit the current through an LED.

The intensity or brightness (call it what you want) of an LED is greatest at a point directly in front of it (on axis). The intensity diminishes the farther you move to one side (off-axis), but it drops off gradually, not abruptly. The beam width of an LED is defined by the off-axis angle where the intensity is reduced to 1/2 of the on-axis value. Sometimes it's specified as the half-angle, and sometimes it's specified as the whole included angle between half intensity points. LED manufacturers can control that parameter by the shape of the plastic lens in which the LED is molded and the location of the light emitting die relative to the focal point. If you look carefully at several different LED's you may notice that the distance from the spherical end of the plastic lens to the chip in the metal cup varies. Generally, the farther back the chip, the narrower the beam angle, although the shape of the lens also has a strong influence. LED's that concentrate their output in a narrow beam give the brightest on-axis intensity, while others sacrifice intensity for a wider usable angle. You can't have it both ways.

The designer of a remote control is tempted to use a narrow beam LED because he can get greater distance, but the downside is that it's like using a rifle instead of a shotgun. A wider beam angle allows the user to be sloppier in aiming the remote at the target, but it must be driven harder to get satisfactory distance. Sometimes you'll notice that the two LED's in a remote are not identical. One is a narrow beam and the other is wider, in an effort to cover all the bases. I believe a great deal of study goes into deciding the best compromise for optimum remote shooting range. For the most part you are stuck with what you get in a particular model remote. It's a myth that the manufacturers use poor quality LED's to save a penny, and that out there in the world are LEDs with two or three times as much light output, just waiting to be soldered into your remote.

3. RCA/PANASONIC CONE TYPE RANGE EXTENDERS. These devices are both a blessing and a curse. The manufacturers like to talk about transmitting through walls and ceilings at distances "up to 100 feet", but actual performance too often disappoints us. FCC limits on allowable transmitter power, coupled with a low product cost budget, dooms these systems to marginal performance. One unit, which I'll call the "transmitter", receives the remote's infrared signal and retransmits it as a 418 MHz UHF radio signal. The other unit, which I'll call the "receiver", receives the radio signal and converts it back into an infrared signal that is blasted out by a bank of IR LED's. The transmitter does not demodulate the IR signal, but rather transmits tiny bursts of UHF corresponding to each LED pulse. The receiver faithfully reproduces each IR pulse, thereby recreating the original carrier frequency. That means the system has no favorites as far as the brand of equipment it is used with. This is in contrast with many published articles describing homemade signal boosters made from a Radio Shack infrared demodulator coupled to an oscillator and LED driver that can generate only one particular carrier frequency.

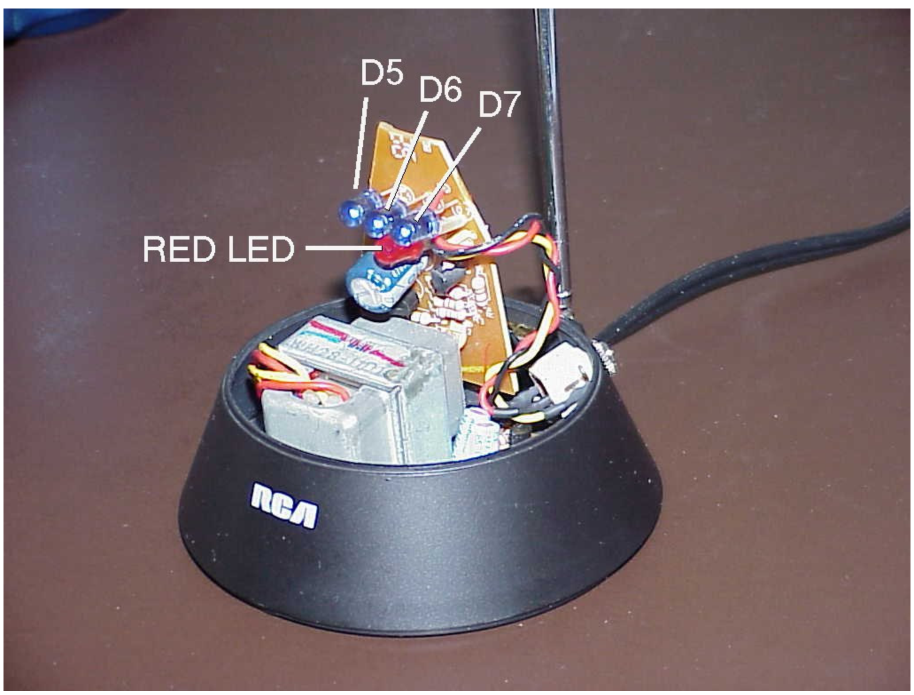

Figure 1. Wireless Receiver/IR Emitter With Top Removed

Figure 1 shows a receiver cone with its top removed, and you can see the array of three infrared LED's and a visible red LED. These collectively provide a pretty good blast of infrared that can be directed toward a whole bank of equipment. For added flexibility there is a 3,5mm miniature phone jack for plugging in an external LED. These come in a wide variety of shapes and sizes, a few of which are shown in Figure 2 on the following page. The three small emitters on the left are frequently referred to as "stick-on IR emitters", for obvious reasons, whereas the three clunkers on the right are intended to be placed out in front of the equipment. Some of these have 2,5mm miniature phone plugs and some have 3,5mm, so be sure to match the connector of your equipment when buying them.

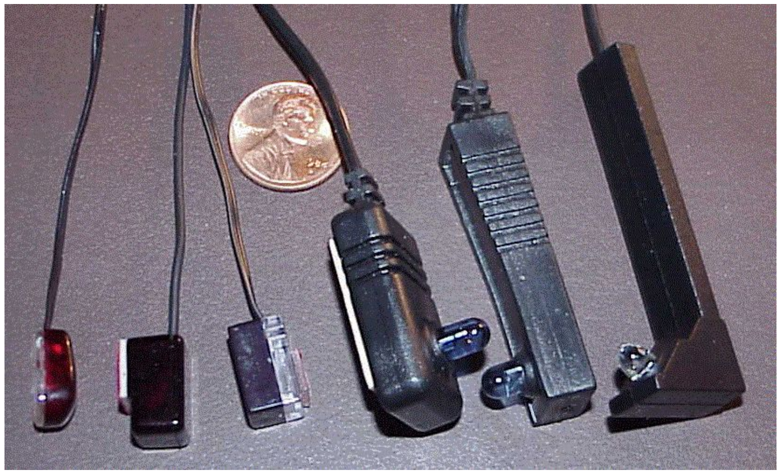

Figure 2. Typical External LEDs

None of these emitters have built-in resistors, because that would make them voltage-dependent. And one nice thing, there seems to be a de facto standard that the LED's positive lead is always connected to the tip of the plug, and its negative lead to the sleeve. Some "dual emitters" (such as the #8171S from Smarthome.com) have two LEDs wired in series, with the same plug polarity as for a single emitter. Some of the stick-on models are IR-transparent, to allow a signal from a hand held remote to pass through the device.

The term "blaster" is one of the most elusive terms used in discussions of IR signal transmission. Often it is applied to the external emitters that are plugged into a base station, sometimes to the base station itself, and sometimes to an infrared transmitting device connected to a PC. Almost any stationary device that reproduces a remote's infrared signal has been referred to as a blaster. A stick-on device hardly needs to "blast" anything at such close range. However, the design of the cone receiver makes no distinction between the internal LEDs, that need to be driven at healthy current levels for distance, and the plug-in ones that don't.

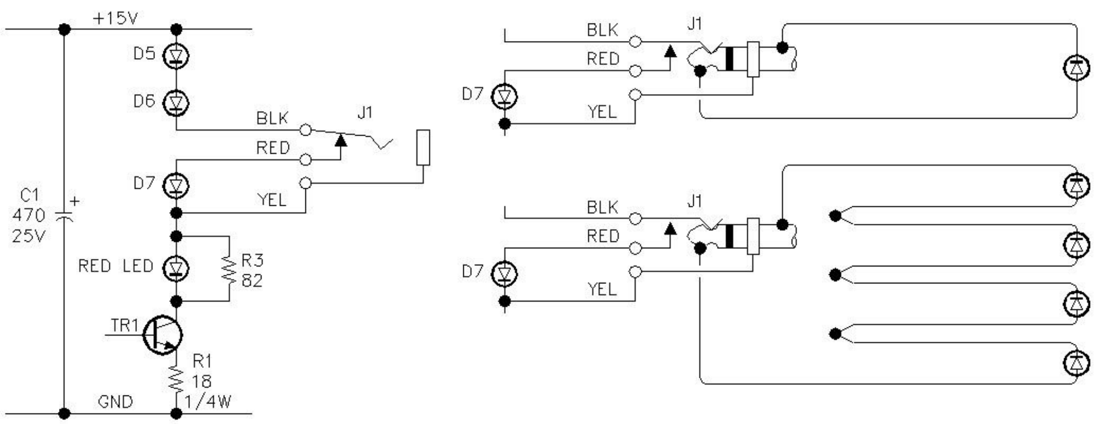

Figure 3. Schematic of Cone Infrared Emitter Circuit

Figure 3 shows a schematic of the essential circuitry related to IR output of a cone receiver. A small transformer and a rectifier bridge supply about 15VDC to capacitor C1. J1 is a switching type miniature phone jack that connects the BLK and RED wires when nothing is plugged in. TR1 is the driver transistor, and R1 controls the LED current. When TR1 turns on, current flows from the positive supply through D5, D6, J1, D7, the red LED, the transistor, and R1 to ground. I'm not sure of the purpose for R3. If it's to route some of the current around the red LED its value is too large to do much good. At high current the red LED drops about 1.8 volts, so the current through R3 is only about 1.8V ÷ 82Ω = 22 mA, hardly enough to make things easier on the LED. The peak pulse current through the entire string with no external emitters was measured at about 240 milliamps.

When an external emitter is plugged into J1 the switch is opened so that the current path is through the BLK and YEL wires, bypassing LED D7. So whether you plug in one or six external emitters (in series of course) they receive the same current as the remaining internal LEDs. The more LEDs you add to the external string, the less the peak current. Approximate peak current can be calculated by subtracting the sum of all the LED voltage drops from the supply voltage, and dividing the remainder by 18 ohms, the value of R1. In reality the calculation is not quite that simple because the voltage drop of an LED varies slightly depending on the amount of current it is carrying, as does the voltage drop through a saturated transistor. So to be sure, I used a 'scope to measure actual current on a sample unit. The following table shows values of peak current under different conditions:

Number. of External LEDs	Peak LED Current in mA
none	240
1	240
2	180
4	100
6	50

If you're going to use the unit primarily to power external emitters you can probably connect up to six of them in series without any problem, because 50 mA is a pretty good current when an emitter is very close to its target. But if you want to maintain the output power of the internal LEDs while also using a bunch of external emitters, or if you want to push those external emitters a little harder, you'll have to reduce the current limiting effect of R1. This is done by either replacing it with a lower value or soldering another resistor in parallel with it. R1 is the resistor with BRN, GRY, and BLK stripes, mounted perpendicular to the board between the yellow wire and transistor TR1. For four external LEDs, replace R1 with 9 to 10 ohms, or parallel it with another 18 to 22 ohm resistor. For six external LEDs, replace R1 with 4 to 6 ohms, or parallel it with an 8.2 ohm resistor.

However, a word of caution. If you modify the unit by reducing the value of R1 the internal LEDs can be damaged if the unit is inadvertently operated without the external emitters plugged in. You should avoid that possibility by cutting the RED wire to J1. Then the internal LEDs cannot be driven unless the external ones are plugged in. For the same reason, don't modify the unit for a string of six external LEDs and then reduce the string to just four.

4. OFA 9910 COMMAND CENTER. The OFA 9910 remote control has a built-in UHF transmitter that transmits at a frequency of 430 MHz, slightly higher than that of a cone. The receiving unit, which OFA calls the "Command Center", is functionally equivalent to the cone receiver. It is packaged in a sleek, low profile enclosure, and has an array of infrared LEDs that blast out through a window in the case. Like the cone, it has a connector for attaching additional external emitters.

Figure 4. Location of Four Case Screws

The four screws that hold the case together are hidden by 1/2 inch square rubber feet on the bottom. Figure 4 shows the feet removed to reveal the locations of the screws. You can either remove the feet each time you want to open the case, or use a sharp knife to remove just the corners of the feet, leaving the screw heads permanently accessible. Note that the pattern is not symmetrical.

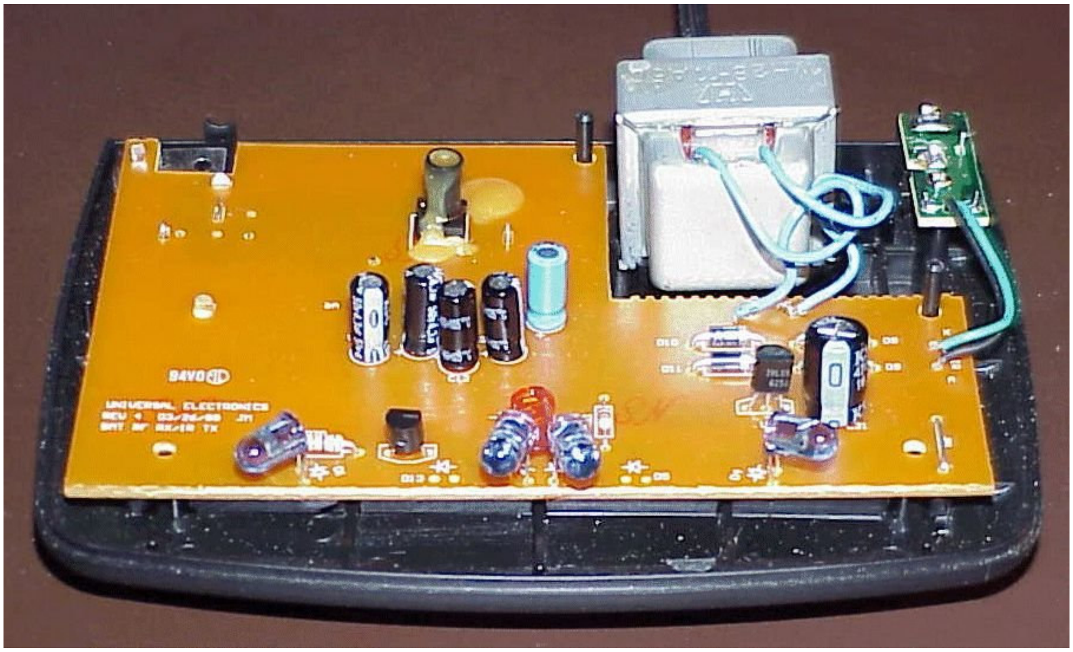

Figure 5.   OFA 9910 Command Center with Top Cover Removed.

Figure 5 shows the main circuit board inside the case, with a smaller board at right rear that holds the miniature 2,5mm phone jack. The power transformer is identical in size and manufacturer to that in the cone, but has only a single secondary winding. As you can see, the unit has four internal IR LEDs instead of three, and instead of pointing in one direction they are fanned out to cover an included angle of 90 degrees or more. That may help in some situations, such as if the unit is placed so that it can control equipment on both sides of a wide screen TV. But if the target is pretty much in one direction there's a lot of energy being wasted by those cockeyed LEDs.

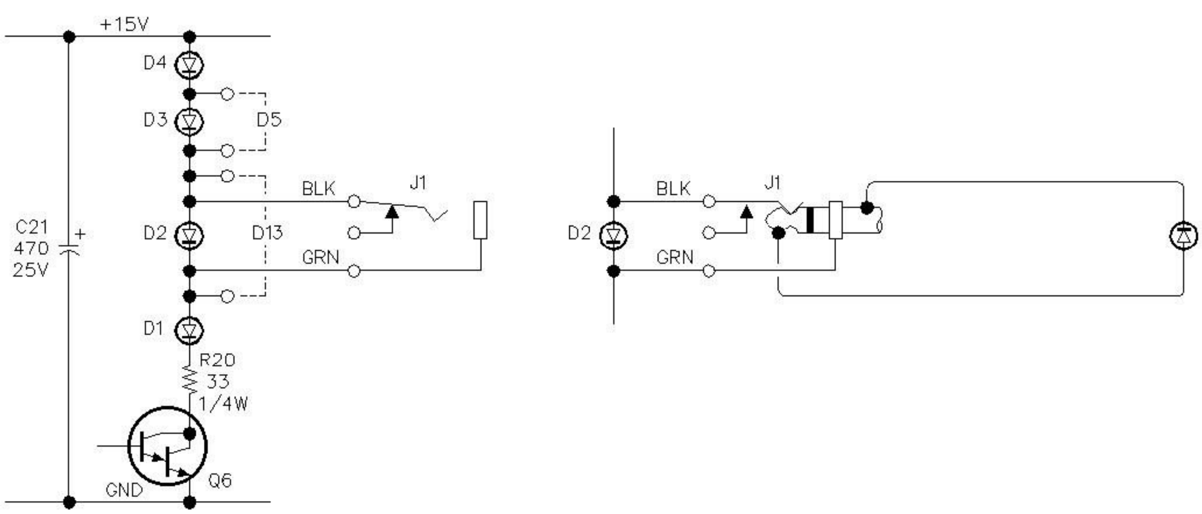

Figure 6.   Schematic of OFA 9910 Command Center Infrared Emitter Circuit

Figure 6 shows a schematic of the essential circuitry related to IR output from the base station. The transformer and a rectifier bridge supply about 15VDC to capacitor C21. J1 is a switching type phone jack, but the switching feature is not used. Q6 is a darlington type driver transistor that drops about 2.5 volts when fully on. R20 controls the amount current through the LEDs. When Q6 turns on, current flows from the positive supply through the four IR LEDs (D4, D3, D2, and D1), through R20 and the transistor to ground. The actual peak pulse current through the LEDs was measured at about 240 milliamps, the same as that of a cone. There is also a red indicator LED, but it's being driven at a much lower current from a completely different part of the circuit. That means the red LED might be blinking even though the infrared components are not. That's not quite as positive an indicator as the red LED in a cone. Actually, about the only thing these two products have in common is their power supply. Everything else is entirely different.

The designer of this product seems to have been obsessed with paralleling LEDs, which is generally not considered good practice. Unless their forward voltages are closely matched they will not share the current equally. The most blatant example is the phone jack J1, which is simply wired in parallel with one of the infrared LEDs, D2. That means that if you plug in a dual external emitter (two LEDs in series) they won't turn on. Since each requires a forward voltage of 1.5 volts, the series pair requires 3.0 volts. But D2 limits the voltage available at J1 to 1.5 volts.

Another strange feature is the provision for two spare LED mounting positions (D5 and D13, shown in dotted lines in Figure 6) in parallel with LEDs D3 and D2. The mounting holes for these are along the front edge of the board, as if there were a plan to provide more than four internal LEDs. In case you're thinking of installing D5 and/or D13 to boost the output, don't bother. Remember the discussion about LED light output being proportional to current? If you parallel D3 with a second LED, each LED in the pair will draw approximately half the current previously drawn by D3 alone, so there's no significant change in net light output. And you can't reduce the size of R20 to increase the current because that will damage D4 and D1, which don't have a partner to share the current with.

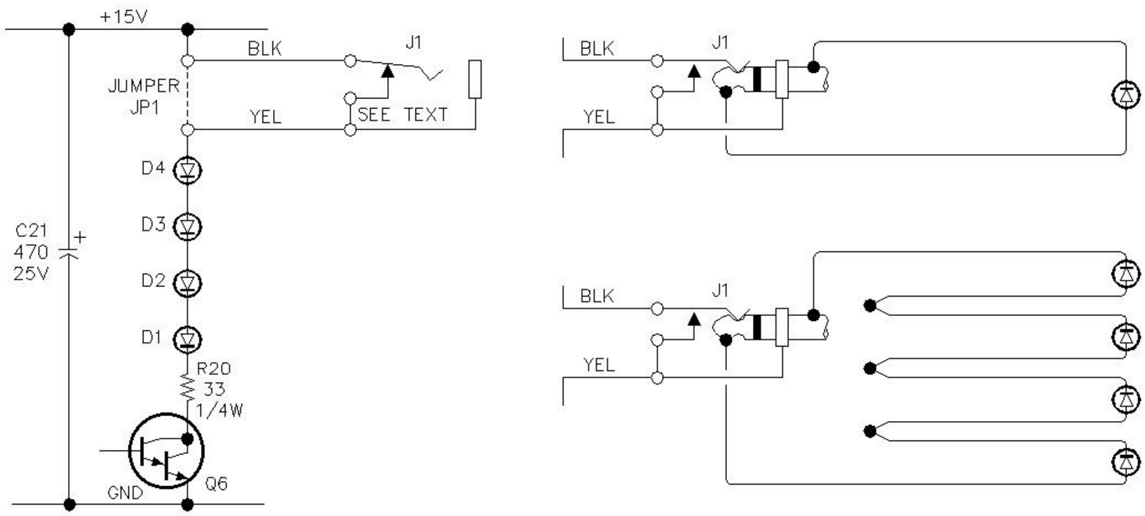

Figure 7. Schematic of Modified 9910 Command Center

Figure 7 shows an easy modification that enables using multiple external emitters while retaining the internal ones. There are a number of variations to this modification, depending on your specific requirements, but this one will satisfy most needs. The most important change is to place J1 in series with the LED string instead of in parallel with just one of the LEDs. That can be done by connecting J1 where the jumper wire marked JP1 is installed, near the front right corner of the board. That jumper is in series with the internal LEDs (dotted line in Figure 7).

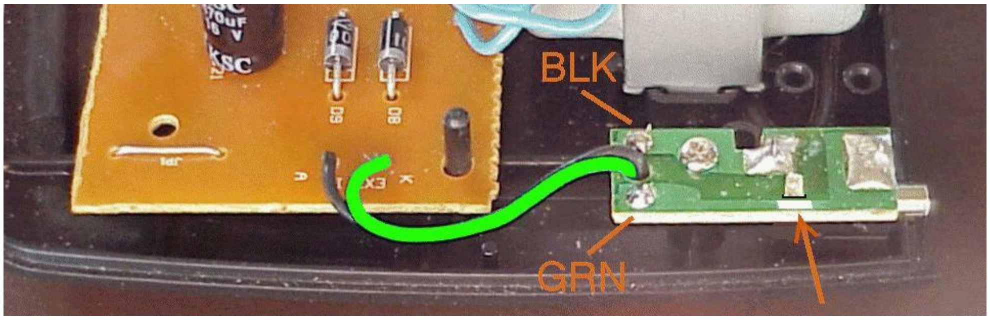

Figure 8. Wiring to J1 Before Modification

As Figure 8 shows, the existing BLK and GRN wires from the J1 board are not long enough to reach the jumper wire position, so start by replacing them with longer wires. Also scrape away the solder mask beside the terminal that sticks through the board (red arrow in Figure 8), to expose the copper clad beneath. A fillet of solder between the terminal and that circuit trace makes the connection shown in Figure 7 that closes the circuit of J1 when the plug is removed.

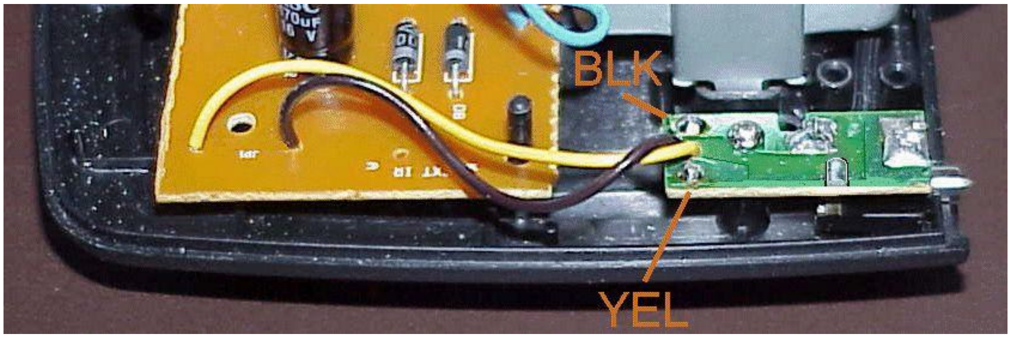

Figure 9. Wiring to J1 After Modification

Figure 9 shows the completed mod. Use any color wires you want, but be sure the wire from the outer terminal of the J1 board goes to the forward jumper mounting hole (yellow wire in Figure 9).

Actual measurements taken on a sample unit gave the following values of peak current under different conditions:

Number. of External LEDs	Peak LED Current in mA
none	240
2	164
4	95
6	58

The result is about the same as for the cone. If (heaven forbid) you need more than six external emitters you have the option of shorting out some of the internal ones. But if you do that you should NOT solder that little spot on the J1 board that ties the edge trace to the terminal sticking through the board. Leave that terminal unconnected so that the external LEDs must be plugged in to complete the circuit. Otherwise, the current will be excessive.

One change you may want to make to either brand of receiver is to redirect the LEDs so they generally point toward your equipment. Both units have their LEDs installed with long leads that can be bent or twisted. In the case of the cone, you may need to fan them out slightly. In the case of the base station you might want to reduce the spread. A word of caution. Hold the LED leads with needle nose pliers close to the board when bending them. The leads are steel, not soft copper, and can pop loose solder pads when you tug on them.

5. MAKING YOUR OWN STICK-ON EMITTERS. Tired of paying $10 or more for stick-on emitters? If you can use a soldering iron, here's a way to build you own that are much smaller than anything commercially available. A good type of infrared LED to use is one sometimes called a "side looker", such as Digi-Key Part No. 160-1063-ND on page 1434 of their catalog, that costs only 24¢. It is a tiny rectangular block about 3/16" x 1/4" and only 1/16" thick, with two leads sticking out one end, and a small bump on one side for the lens. While the lens is the exit for the strongest signal, there is enough internal reflection to provide a usable signal from the back side too. The Xantech Model 282M "Mouse Emitter" uses a similar LED and places it with the lens facing away from the adhesive side. That way, if the unit is applied directly to a window the lower intensity rear output is sufficient, and if the unit is applied to a door or shelf a few inches away from the window the higher intensity front output is available. You can try the rear output first, and if that doesn't seem to be sufficient, just remove the lens by filing or sanding it off, to give you a flat mounting surface on the side having the strongest signal output.

You'll also need a miniature phone plug like those shown on page 274 of the Digi-Key catalog. For the cones, use the 3,5mm plug, Part No. CP3501-ND, and for the 8910 base station use the 2,5mm plug, Part No. CP3501-ND. Either of these costs 76¢. You can make a very small and flexible cable with a pair of conductors split from a piece of flat ribbon cable. But you may have to use bulk cable, since there aren't any old ribbon cable assemblies more than three feet long to salvage wire from. Digi-Key sells 10 feet of 10-conductor cable for under $2. See Part No. MC10G-10-ND on page 37 of their catalog.

At the LED end, split a pair of wires back about an inch and slide on 1/2 inch lengths of very small heat shrink tubing. Strip and tin both wires about 1/8", lay them against the LED leads and make your solder joints as small as possible. Slide the tubing over the leads and shrink them with a cigarette lighter if you don't have a heat gun.

If you're making a 4-LED array, start with a piece of 8-conductor ribbon cable and split it into pairs except for the last few inches at the connector end. Solder an LED to each of the four pairs as described above, taking care that the positive leads (anodes) are connected to wires 1, 3, 5, and 7, and the negative leads (cathodes) to wires 2, 4, 6, and 8. Split all eight wires back an inch at the connector end, and strip the insulation about 1/4 inch. Twist wires 2 and 3 together, solder them, and insulate them with some sleeving. Do the same with wires 4 and 5, and 6 and 7. That connects all four LED's in series. Now solder wire 1 to the tip, or center contact of the miniature plug, and wire 8 to the sleeve, or outer contact.

There are any number of ways to fasten an LED to the window of a device, but try to use a method that can be removed without disfiguring the window, not a solvent-based cement. Even a very small spot of hot melt glue will secure the emitter, yet can be popped loose from the smooth surface of the window. With very tiny emitters like these, a piece of ordinary packaging tape or Scotch tape will hold them in place. Some of the commercial units use transparent double-sticky tape, but the plain vanilla double-sticky foam tape that's about 1/32 inch thick and beige in color is sufficiently transparent to infrared wavelengths that you can use it. There's also an item usually available at office supply stores called "transfer tape", which is a thin, transparent tape with adhesive on both sides.

6. PROBLEMS WITH SPONTANEOUS OUTPUTS. A common complaint with UHF extenders is spontaneous IR emission from the receiver unit. Here is a common scenario. Your receiver is sitting on a table in your family room, and pointed at some equipment that you want to control from your bedroom with a UHF transmitter. You notice that at times you have a lot of trouble controlling things, sometimes even when you're in the family room pointing your remote directly at the equipment and not even using the UHF link. Sooner or later you notice the little red LED in the receiving unit coming on from time to time when it shouldn't.

The culprit is usually RF noise being picked up by the UHF receiver, which triggers an IR output signal. If there's enough noise present, the output can jam the IR receivers in your equipment so that the remote's signal can't get through. The problem stems from the low cost design of the UHF transmitters and receivers that gives them a wide bandwidth. The wider the bandwidth the greater the chance of picking up random noise from other devices that emit RF energy. Unfortunately, there's no simple solution. Standard troubleshooting procedure is to try a different location for the receiver, experiment with the extension and orientation of the antenna, and try turning off nearby equipment that might be causing the interference (including wireless phones and microwave ovens). I once had a cone receiver in my family room that was such a nuisance I made a dunce cap of black paper and dropped it over the cone any time I came into the room to watch TV. That didn't solve the problem, it was just an easier way than unplugging it to shut off the unit when it wasn't needed.

If you plug a small speaker (any impedance, any size) into the phone jack of a cone receiver or base station it makes a handy little audible detector for RF noise. The larger the speaker the louder the sound. If the receiver is occasionally picking up RF noise you'll hear random "clicks" like those of a Geiger counter. Lots of clicks means lots of noise that might interfere with normal operation. When you transmit from your remote it sounds like a steady buzz, somewhere between a rattle snake and a motorcycle. This can make it easier to search around for noise sources, or to find a noise-free location for the receiver, without trying to watch the dim little red LED. It can also be used to verify if the receiver in another room is picking up your remote signal. A small speaker enclosure, perhaps an abandoned shelf speaker, can be heard from quite a distance.

There have been a few posted messages advocating a modification to the 9910 base station that reduces its noise sensitivity. The unfortunate byproduct is that it also reduces its sensitivity to the remote signal. You may be able to reach a compromise where you reduce noise pickup to a satisfactory level, and can still receive the remote transmission, but it's a hit and miss proposition.

There is a special case with cone systems that can cause behavior similar to the spontaneous output problem, but it isn't caused by noise. These devices are intended primarily for use where the transmitting unit is out of sight of the receiving unit. If they are located in the same room, or even so there can be indirectly reflected infrared from the receiver back to the transmitter, there can be a problem with regenerative feedback. The system goes into high frequency oscillation that disables it. The phenomenon is analogous to the high pitched squeal sometimes caused by audio feedback from speakers to the microphone in a PA system. It's easy to diagnose this problem by unplugging the transmitter cone to see if the red LED in the receiver stops flashing. If it keeps flashing, the problem is probably RF noise interference rather than feedback. The 9910 base station doesn't exhibit this problem because the remote has no capability to see the infrared transmissions from the receiver.