THINK TANK

By John J. Yacono

Current-Limiting Resistors and More

As its name implies, a current-limiting resistor restricts the amount of current flowing through a branch of a circuit. They are usually used to protect some current-sensitive device in series with them. Some of you who are new to electronics may not know how to calculate the value of current-limiting resistors to use in your projects. Even if you do, there are a couple of important considerations you should keep in mind that many hobbyists overlook. With that in mind, I'd like to present a couple of the basics for choosing the best value of current-limiting resistor for three common circumstances.

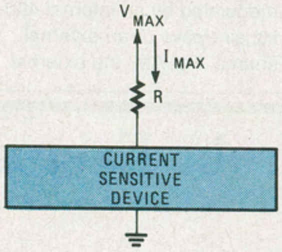


Fig. 1. Most current-limiting resistors are simply placed in series with the devices that they are supposed to protect.

The most-common and simplest configuration for using one is shown in Fig. 1. In that circuit, there is a current-sensitive device (such as an LED) protected by a current limiting resistor, R. They are connected in series to some voltage source (a power supply or perhaps some other circuit) whose maximum output voltage is denoted V_{MAX}.

To figure out the best value for the resistor, R, we take the maximum voltage and divide it by the maximum current (I_{MAX}) that the sensitive device can handle; you can usually find that value in the device's application notes or specifications. Effectively that limits the current flow to a safe value (I_{MAX}) even if the current-sensitive device acts like a dead short.

Although usually overlooked, you should also determine the wattage of the current-limiting resistor. Not checking the wattage needed is a ready invitation to disaster. The wattage (P) can be determined from:

$$P = I_{MAX}{}^2R$$

When you calculate R and P, you'll probably get values that can't be found in the real world. If so, use a resistor whose resistance and wattage slightly exceed the values you've arrived at. That provides the circuit with a little extra protection.

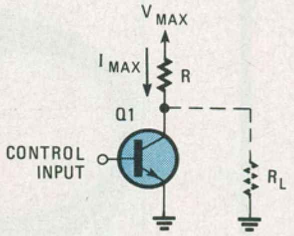


Fig. 2. A current-limiting resistor in a transistor-switch circuit protects the transistor, but it also limits the output voltage and current.

Another common circuit that requires a current-limiting resistor is a transistor-switch (see Fig. 2). In that circuit, when current is applied to the control input (in this case, the base of the transistor), Q1 turns on and current flows through R and Q1's collector and emitter to ground. Resistor R limits the current flow to a safe value exactly as it did in the previous circuit. In fact you, can use the principles we've already described to determine its specifications.

However, there is one extra consideration to take into account: the load impedance, represented by the dashed resistor, R_L, in the circuit. It is drawn dashed because the load may be something other than a resistor; for instance it could be another transistor stage or an op-amp input. The load impedance is important because R limits the current and voltage available to drive the load. The maximum current through the load (I_L) will be:

$$I_L = V_{MAX}/(R + R_L)$$

If the value of load current is too small, you will have to lower the value of R and chose a transistor that can handle the additional collector-emitter current to replace Q1. Recalculate the wattage of the resistor too, just in case.

If the load is a voltage-sensitive device (such as a FET), then you'll need to determine the maximum voltage (V_L) the circuit will deliver to the load. Use this equation for that:

$$V_L = (V_{MAX} R_L)/(R + R_L)$$

The last use for current-

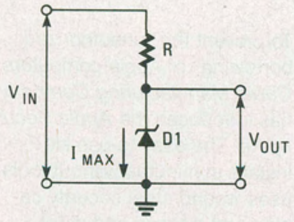


Fig. 3. Zener diodes make excellent regulators. However, the current-limiting resistors they require reduce the maximum output current as well as the voltage.

limiting resistors we'll discuss is to protect Zener diodes (see Fig. 3). In Fig. 3, we show a Zener diode acting as a voltage regulator. With the help of the resistor, it is used to reduce an input voltage (V_{IN}) to a desired output voltage (V_{OUT}). As you probably know, the Zener diode you chose determines the output voltage. The Zener diode can only pass so much current, and we'll denote the maximum current as I_{MAX}. The resistor value needed to protect the Zener can be determined by:

$$R = (V_{IN} - V_{OUT})/I_{MAX}$$

The load connected to V_{OUT} will be subject to the same current and voltage restrictions that we mentioned in our discussion on the transistor switch. In fact, you can use the same equations for V_L and I_L to determine the maximum values, provided that you do two things: substitute V_{IN} for V_{MAX}, and remember V_L will not rise above V_{OUT} no matter what the equation says.

And now onto the mail. As always, my co-conspirators in this month's column will receive a copy of Think Tank II. If you've contributed to this column before and already have a copy, let me know and we'll find something else to send you.

PHONE-RING DETECTOR

Most telecommunications products are capable of automatically answering the phone to perform their tasks. They normally let the phone ring a few times and then answer the call. You can add that feature to your own telephone-line connected projects with the simple circuit shown in Fig. 4. Optocoupler U1 isolates the circuit from the telephone line. Transistor Q1 acts as a buffer that allows C2 to charge each time it receives pulses (the ring signal) from U1.

The transistor also helps detect degraded ring signals. Op-amp U2 is used as a comparator that will go high when C2 is sufficiently charged (seven rings to be exact). The op-amp output can be used to trigger your own project, take the phone off hook, or whatever.

—Tony K.P. Wong, Robinson Heights, Hong Kong

I like how D1 helps protect the LED in U1 from overvoltage. Note that the timing constant of R6 and C2 is such that the circuit will not be fooled by dialing pulses.

TELEPHONE INTERCOM

The church that I attend needed an intercom with

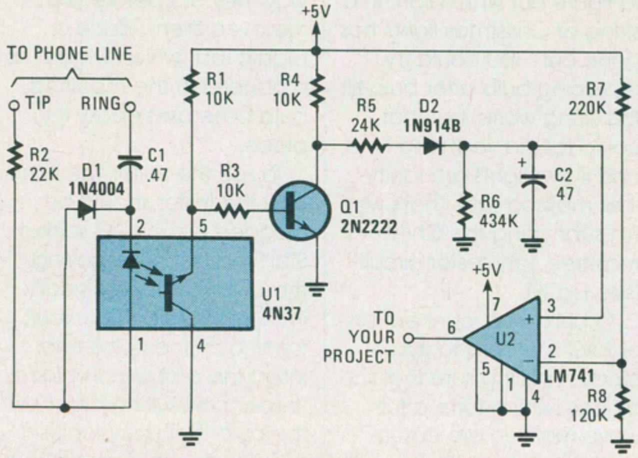


Fig. 4. This ring detector can be a great front end to a phone-answering project. You can alter the value of R6 and C2 to change the number of rings that activates the device.

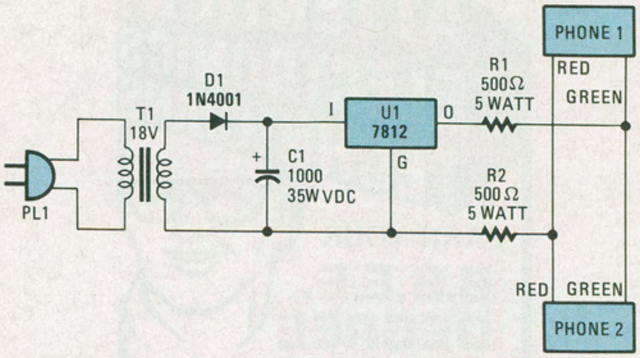


Fig. 5. If you've got a couple of old phones lying around, then this phone intercom might get your interest. You just need a very simple power supply or batteries and a couple of high-wattage resistors and you're all set.

two stations. There was no need for a ring signal. I wanted to make it simple, but with good quality sound.

Remembering that I'd seen a way to connect two telephones together, I came up with the circuit in Fig. 5. It uses two telephones and a power source that form an excellent intercom. The red (ring) wires of the phones are tied together, the green (tip) wires are connected together, and the two sets of wires are connected to the power source via two 500-ohm, 5-watt resistors.

The resistors are the key to making the phone intercom work; they isolate the phones from the power supply, permitting AC audio signals on the phone line. Without the resistors the red and green wires would be clamped at the DC-source voltages.

The power-supply voltage is not critical—the intercom will work on 5- to 50-volts DC. However, if you use an AC power supply, a voltage regulator is a must. On my first try at this circuit, I did not use one and got an earful of hum.

A 12-volt car battery will work for a portable system. I think others will find this circuit easy to build and very useful.

—*Vincent Grabosky, Ruffsdale, PA*

If I'm not mistaken, you could probably use one 1000-ohm resistor in place of the two 500-ohm units. Of course, you'll have to either use it between the ground and red lines or the positive supply rail and the green wires.

There may be some potential for using the same type of idea on a household telephone system to turn extensions into intercoms. You would probably need a 90-Hz oscillator to provide a ring signal to get someone's attention.

CHRISTMAS-LIGHT TESTER

How often have you been out in the cold trying to figure out which light in a string of Christmas lights has gone out? You could try replacing bulb after bulb till the string works, but that could take a very long time, and if two lights are faulty that method fails. That's why I'm submitting this Christmas-tree light tester circuit (see Fig. 6).

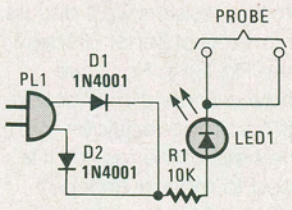


Fig. 6. This little project could help you keep the holiday spirit alive next winter. It will help you quickly trouble-shoot bad Christmas-tree lights so you can spend your time enjoying the festivities.

To build one, connect an old AC line cord to two diodes making sure that the diodes (which form a full-wave rectifier) are connected as shown in the schematic and their leads are insulated. The remaining leads of the diodes should be tied together and connected to a 10,000-ohm resistor. The resistor should be connected to the anode of an LED. The cathode of the LED should be connected to a length of stranded wire. Insulate all the leads with heat-shrink tubing or electrical tape and house the whole assembly in a tubular enclosure with the LED visible from one end.

The wire will be connected to a probe made from a dead bulb. First remove the glass bulb from it's base by giving it a pull. Now twist the wires on the bulb together a couple of turns, attach the stranded wire to the twist and solder the three wires together. Snip the assembled junction from the bulb and place the wires back in the base so they protrude the way they did before you removed them. Place a plastic rod (which will act as a handle) in the modified bulb base and epoxy it in place.

To use the tester, the lights and the tester should be plugged into an AC socket. Start the test by removing the bulb that is electrically in the middle of the circuit formed by the bulbs and insert the probe in its place. (Inspect the wiring carefully; the bulb that's physically in the middle of the string is not necessarily in the middle of the circuit.) The LED will light if the socket is getting power from at least one side of the socket.

Now you need to determine which half of the circuit is not providing power. Remove one of the bulbs next in series to the socket you're testing (again, do not assume that bulbs physically next to each other are connected in series); if the LED remains on, then the fault is in the leg that contained the bulb you just now removed. Of course, if the LED goes out, the fault is in the other half of the circuit. By determining which side the fault is on, you have cut the possibilities in half.

Remove the probe, replace the bulbs, and put the probe in a socket half way along the faulty side. Determine which side of that socket is not getting power as you did with the first socket. If the fault lies somewhere between the last and current sockets tested, then test a socket about halfway between them. If the fault is on the other side, test a point halfway between the current socket and the end-most socket. Keep proceeding in that manner, testing points halfway between sockets you've tested, till the string lights up. Remove the probe and put a fresh bulb in its place.

If the LED doesn't light in a particular socket, then there are at least two bulbs out (one on either side of the socket being tested). Use the same method of dividing suspect legs of the circuit in half and test again; only keep in mind that the string will only light up when you find the last faulty bulb. Instead you'll know you've found a faulty bulb because the LED will light when connected to a socket on one side of it.

I would like to emphasize how much I appreciate *Think Tank*. I don't have time for lengthy projects. Your projects are quite manageable and most of them are very ingenious thanks to your readers and your selection. Keep it up!

—P.T. Chopping, Allison Park, PA

You've just helped me reduce the time and drudgery involved in a chore I've never liked. If anybody feels a little uncomfortable about connecting an LED to line voltage I think you could probably use the same technique with DC voltage provided you reduce the value of R1 (just like we discussed in the beginning of this month's column).

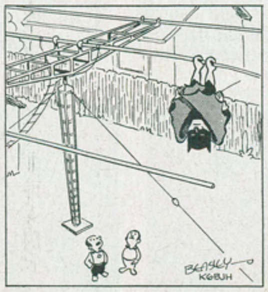
SOLDERING HINT

I use rubber bands to hold components to a printed-circuit board during soldering operations. It's easier than bending the leads the way I used to do, and I've found that bending the leads can cause unwanted shorts.

—Al Williams, Jasper, FL

See Al? That's all it took to win a book for you. Good going!

Well that brings us to the close of another month. As usual, all the submissions we use are rewarded with a copy of Think Tank II. So get the mailman hop'in by sending your circuits and ideas to *Think Tank*, **Popular Electronics,** 500-B Bi-County Blvd., Farmingdale, NY 11735. ■



"I know even super heroes have to sleep somewhere, but he's de-tuning my beam."