INTERFACING WITH THE TELEPHONE NETWORK USING THE MPC-2

HAZARDOUS VOLTAGE DISCLAIMER

Hooking up projects to your telephone lines can involve potentially harmful or dangerous Voltages that can injure or kill. While the Phone company takes great care to assure that no dangerous Voltages are ever present on your phone lines, many people each year are killed or injured as a result of lightning or other Voltage surges on their phone lines. You must also be sure that you do not induce hazardous Voltages on the phone lines by your actions. Doing so may cause injury or death to telephone service persons or others and may destroy telephone company equipment for which you will be liable. If you are not sure exactly what you are doing, be responsible and don't hook anything to your phone line.

INTRODUCTION

Many projects require some kind of connection to your phone line. Telephone remote controls, conversation recording devices, audio send, receive, or send/receive (hybrid) interfaces, modems, auto dialers, caller-ID boxes, auto-answer listen lines, ..the list goes on. Until 1979, it was illegal to hook anything up to your phone line without connecting it through an AT&T leased coupler. Anyone caught with a second phone or other product connected to the phone system risked having it confiscated. In 1976 the FCC drafted some basic rules that were supposed to standardize connections to the phone network and make it possible for anyone to build a product that could be certified for use on the network. Those rules were the beginning of the FCC's part 68. AT&T, trying to protect its monopoly, fought the new rules all the way to the supreme court where they eventually lost. Since that day, there have been over 100,000 products licensed and part 68 is now several hundred pages long. Three major objectives are at the heart of the rules. First, the FCC wanted to make sure that anything connected to the phone line is safe for the user. Because of their length, phone lines are subject to occasional high voltage spikes from lightning and other sources. Connected devices must be able to withstand and dissipate a significant energy surge. Second, it is important that the device not be able to damage the phone line or injure phone service people. If an improperly designed device's power supply fails while it is connected to the line, dangerous Voltages could be present. Such charges would probably damage the system and possibly be fatal to an unsuspecting repair technician. Third, whatever happens on your phone line should not degrade your conversation or anyone else's. Malfunctioning or poorly designed equipment can cause distortion, hum, and low levels on your phone. Phone lines often run many miles in unshielded, twisted pairs. Your conversation may run that entire distance only a few microns away from other pairs carrying conversations, data, etc. The system works because the phone company goes to great lengths to be sure that each pair is perfectly balanced, filtered and that all signals are below certain levels. If your line becomes unbalanced or you exceed the signal limits, you may cause problems for yourself and everyone else that shares a cable with you. It is amazingly easy to mess up a phone line. Just connect one side of the line to ground. You will probably get so much hum and noise on your line that you won't be able to use it. The FCC also knows that even well designed and built equipment will eventually fail. When that happens, it must be constructed so that it fails completely and is unusable. The reason for this rule is to make sure that the user knows there is a problem and to be sure that malfunctioning gear can't damage the system. With a little thought, it is easy to design an inexpensive interface that can meet the FCC requirements.

THE CIRCUITWERKES MPC-2 .

In this paper, we will discuss how to design and build a type-approvable (meets all technical requirements in the FCC rules part 68) protective voice coupler that is caller ID compatible and has features including ring detection, line current detection, and a host of technical requirements that make it compliant with the FCC's rules. A version of this device, called the MPC-2, has already been designed and is available from CircuitWerkes at (352) 335-6555. Complete plans and PC Board layouts for the MPC-2 are presented later in this paper.

HOW YOUR PHONE LINE WORKS

Before we can begin the design process, we need to know a little about how the phone line works. The phone line coming into your home ends up attached to an RJ-11 (modular) jack. For a single-line installation, two conductors called Tip and Ring* make up the phone line that connects your telephone equipment to the phone company's Central Office, CO for short. When your telephone instrument is on-hook (hung up) the tip and ring conductors have about 48 volts dc, called battery voltage, between them. Note that this voltage is current limited, varies between companies and is NOT referenced to ground. When your phone is picked up, the battery voltage is loaded down and the voltage drop on your line is detected by the CO. The CO takes this drop in battery voltage as a signal that you want to make a call; it switches dial tone onto the line and waits for the dial pulses or DTMF tones that make up your dialing. When you are on the receiving end of a call, the CO switches a ring generator onto your line that makes your phone ring until you pick up. The ring signal is a low frequency ac pulse that rides on the dc voltage. Most telephone instruments capacitor couple the ring signal to an attention getter like a bell or one of those irritating piezo buzzers. When you pick up the phone the CO gets the dc voltage drop signal, stops ringing your line, and hooks you up to the calling party. An obscure but important note...when the calling party hangs up, the vast majority of CO's in the US send a short battery reversal or zero voltage signal to the receiving party (if it's still off hook) followed by another one about eight seconds later. Most CO's also dump dial tone back on the line after a short time as well. We acknowledge that we've left out a bunch of HOW THE PHONE COMPANY WORKS, but this article is about a telco interface; and we have included enough basic information here to begin to design a working protective voice coupler. If you are really interested in the rather complicated total operation of the phone company, we heartily recommend a book formerly carried by Radio Shack (yes Radio Shack...) called Understanding Telephone Electronics, It is an extremely well-written, surprisingly complete and utterly cheap source of good Telco information. Unfortunately, it appears to be out of print as of 1992, but may be available at your public library.

What the MPC-2 Does

The MPC-2 was designed to be very simple and very flexible. The electronic components involved are inexpensive and easily obtainable. Because of the protective (isolation) nature of the coupler it must be built exactly as described in this article to definitely be type-approvable. Any variance from the construction details in the article or from the component values specified may greatly reduce the likelihood of your coupler being FCC approvable.

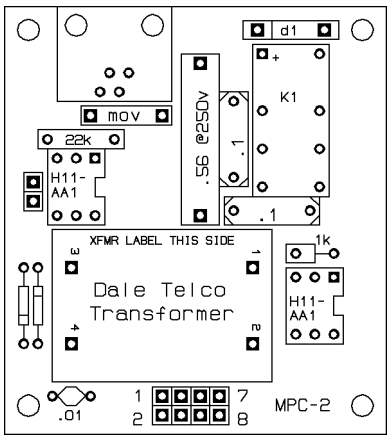


Figure 1 (on page 4) is the schematic diagram of the MPC-2 coupler. The telephone line's TIP and RING attach to the coupler board through an RJ-11c (modular) jack. Not just any RJ-11 type jack will work. The jack you use must comply with the mechanical and (gold) plating requirements in the FCC rules. Only a few of the RJ11 jacks sold worldwide can meet the FCC's gold plating standard of 50 microns. The parts list in the sidebar offers a few sources for these jacks and other parts in the coupler. The tip line is connected to C1, a .56uF capacitor rated at 250 Vdc. This capacitor allows the ac componant of the incoming ring to reach pin 2 of U2, an H11AA1, ac input, optocoupler. Pin 1 of the H11AA1 is connected to the phone line's ring through series limiting resistor R1. The output pins of U2, which go low during an incoming ring, are connected to the user interface header. This output can be used to signal your logic whenever a ring is received. The tip line is also connected to C3, a .1uF, 250 Vdc capacitor which, along with C4, passes caller ID line audio to transformer, T1. T1 is extremely critical to the operation of the circuit. It provides a 1,500 Volt isolation from the phone line, and the correct dc resistance to tell the CO that the line is in use, and it assures that the phone line will be properly balanced. K1 is a standard, pc mountable, DPDT, dip relay with a 12 Vdc coil. Note that there is a generic (1N4001 or equiv.) diode across the coil of K1 to suppress back emf when the relay energizes. That makes the relay connection polarity sensitive. When de-energized, C3 and C4 are connected to T1 allowing the monitoring of the phone line by caller ID readers or other devices. When K1 is energized, the tip and ring are connected directly to T1, seizing the line and passing audio to the secondary.

U1 is a line current sensing optocoupler. When the unit is on-line, (K1 is energized) the potential between the tip and ring turn on U1. When the end of call battery reversal occurs, U1 shuts off for a moment signalling your external logic that the call is over. V1 is a 300 Volt MOV. This value was used because some phone systems, particularly rural routes, often have elevated operating voltages. It is not uncommon to find a phone line with a nominal 75 Vdc on-hook value and a ring voltage of 100 Volts. In this case, a 300 Volt MOV provides sufficient overhead to prevent clipping the phone company's voltages.

The final componants in our coupler provide signal limiting and waveform shaping to meet FCC specs. Two germanium diodes, D1 & D2 are used to limit signals to the required -9 dBm limit set by the FCC. Because -9 dBm corresponds to about .25 volts at the nominal 600 Ohm line impedance, only diodes with a very low breakdown voltage will work. You cannot use either standard silicon or any type of zener diode as a limiter because the breakdown voltages are too high. Fortunatly, some germanium diodes do break down at about the right voltage. C2 is a .01 uF mica capacitor that absorbs high frequency harnonics generated by the clipping action of the diode limiter or introduced at the audio input terminals. While frequencies above 3 kHz are filtered in the phone system, the rules require some hf suppression to prevent cross talk with other pairs in your trunk line.

The MPC-2 passes (limited) audio from Tip and Ring to pins 2 and 4 of the 8 pin header whether the unit is on-hook or off-hook. This feature makes the unit compatible with many caller ID systems. Incoming ring voltage causes an isolated open collector output at pins 1 and 3 of the header. When the unit is on-line an open collector output occurs at pins 7 and 5. When the calling party hangs up the optocoupler turns off momentarily, signaling that the call is over. Applying 12 volts DC to header pins 6 and 8 will cause the MPC-2 to go off hook. Simple logic circuits can control the MPC-2 while monitoring its ring detect and line current detect lines.

1 The designations, Tip and Ring, come from the old days when telephone calls were manually switched by an operator on a big patch bay. The connections were then made by cables with connectors that resembled a standard 1/4" phone plug. Tip and Ring referred to the tip and ring of the connector where the "live" phone line was connected.

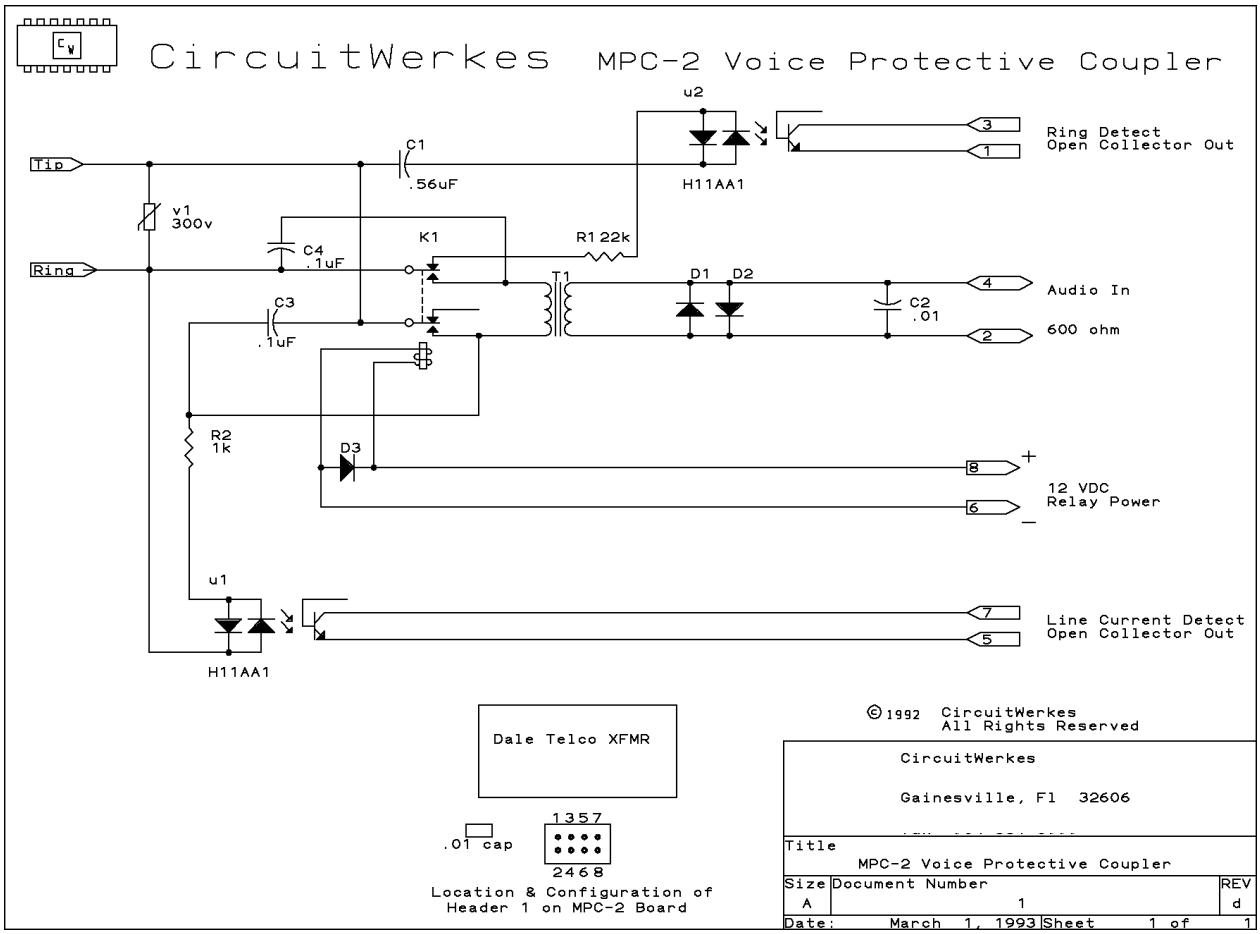


Figure 1. The MPC-2's Schematic diagram.

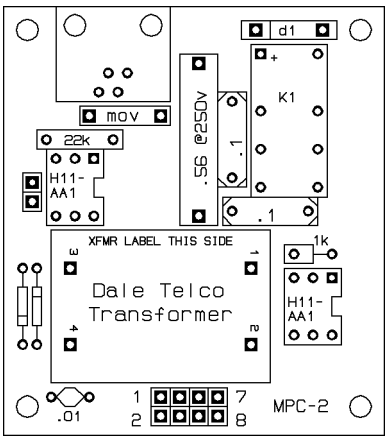
CONSTRUCTION

Assuming that you've fabricated your own board and found your own parts, you are now ready to proceed with construction. First install and solder the low profile components, 22k resistor (red-red-orange-gold color code), all three diodes, and the MOV (tan colored, cylindrical, two-leaded device). Be sure that each diode (the encircling band on the component is represented on the PC Board's silkscreened legend) is oriented correctly before soldering. Then add the sockets followed by the 1k standup resistor (brown-black-red-gold color code) and the the .01 uF disc capacitor. The relay, the three 250V capacitors (a pair of .1 uF and one .56 uF) and the telco transformer can be placed next. Place the transformer with its dot toward the two back to back 1N270 diodes. Then snap the fifty micron gold plated RJ-11 jack into the holes on the board, being careful not to bend the pins on the bottom of the jack. Make sure the jack is seated firmly against the board all around, then solder it on. The 8 pin header pin (2x4) strip is convenience item; you can optionally just solder wires to the header pads on the pc board.

Assembled and tested MPC-2s are available from CircuitWerkes at (352) 335-6555 (fax) 380-0230. info@circuitwerkes.com

Complete kit of parts for MPC-2 ..... **Discontinued**.
Assembled, TYPE APPROVED, MPC-2... $39.95
Various individual parts can also be purchased from Hosfelt Electronics, Digikey, B.G. Micro, Radio Shack, Mouser, and no doubt many others.

PARTS LIST:



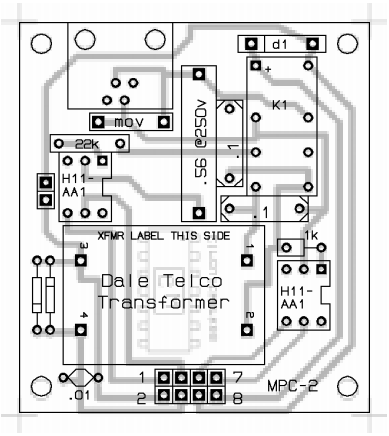
1) MPC-2 PC Board
1) RJ-11c jack (50 micro-inch gold-plated) right angle pc mounted telephone jack
1) Dale TA-40-01 or equiv. Telco Transformer
1) 300v Axial MOV
1) 12vdc or 5vdc DPDT Dip Relay
1) 1N4004 (or equivalent) diode
2) 1N270 diodes
1) .56uF 250v mylar capacitor
2) .1uF 250v mylar capacitors
1) .01uF 50v disc capacitor
2) H11AA1 AC input optoisolators
1) 1k 1/4w resistor (brown-black-red-gold color code)
1) 22k 1/4w resistor (red-red-orange-gold color code)
2) 6 pin DIP sockets
1) 8 pin (2x4) header (optional - see text)

PRE-TESTING THE MPC-2

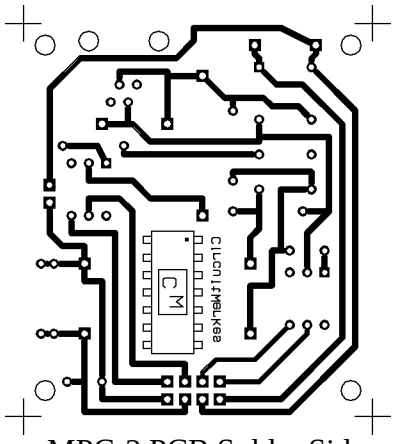
Testing of the MPC-2 should be performed before it is connected to the phone line. The tests should include at least the following:

1) No dc path from tip to ring (with relay de-energized)
2) No dc path from tip or ring to any of the pins on the 8-pin header.
3) Verify that the transformer is oriented properly (as described above), and that the two limiter diodes are oriented in opposite directions.

Figures 2a & 2b - The MPC-2 Layout



MPC-2 Board & Parts Layout



MPC-2 PCB Solder Side

About FCC Part 68 Type Approval:

In addition to spelling out the technical requirements for telephone equipment, the FCC rules require that every piece of equipment (even home brew and hobby kits) connected to the phone lines be registered with the FCC. It is not enough to simply design a device that can meet the specs. Every product must be tested, certified and registered. While many people have never heard of this requirement, the rules are very clear. Individuals who connect non-registered devices to the phone line risk anything from simple confiscation up to fines of $10,000 per day for each device you have. In addition, using a non-registered device makes you liable to the phone company for any damages incurred as a result. So with all that at stake, why doesn't everyone just register their gear? Well, you could start with the $155.00 fee that the FCC charges you each time you register a new gizmo. Usually, that $155 is just the tip of the iceberg. The tests required are complex and some unusual and expensive equipment is needed. Certification by a testing lab can run from $2,000.00 to $3,500.00 for a simple one line device. The prospect of spending upwards of $2,000.00 a bit much if you're a hobbyist and want to make a little phone "project" for yourself, which is why CircuitWerkes has made pre-built and tested MPC-2s with pass through FCC registration available to you for a reasonable cost. Pre-built and tested MPC-2s come with pass through FCC registration for voice service use and include a registration label and all necessary paperwork to insure that your device is FCC legal.

Sample schematic for making an automatic coupler using an MPC-2.