Interfacing Audio & POTS

(Plain Old Telephone Service)

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Introduction

In the USA, in spite of all the hoopla about digital-this, digital-that and fiber-optic-whatever, the truth is that many small commercial paging and music-on-hold applications still involve interfacing with the plain old telephone service, or "POTS". (*By contrast, if you work in the EU business place, then you will rarely run into POTS, since it has almost all been converted to ISDN.*) Meanwhile, back in the USA: if you are lucky, the telephone system you get to work with will provide a line-level auxiliary analog audio feed, but if not, then this Note's for you.

Analog Telephone Overview

An analog telephone line, at its simplest, is nothing more than a 600 Ω balanced line. One pair of wires carries duplex[1] audio and 48 VDC for telephone operation. The 48 VDC is current limited by series resistors (one in each leg), therefore phones "on-hook" (no current drawn) typically measure 48 VDC, while phones "off-hook" (current drawn) typically measure 6-8 VDC.

Basically all phones work the same, yet many different systems coexist throughout the word. Major differences are found in wiring practices and connectors, line impedances, and loop currents, signaling tones and safety regulations. International harmonization is slowly changing this. The system described here is typical for the United States.

Long distance lines separate transmit and receive audio paths and use 4-wire cable (two pairs). Converting 2-wire local wiring to 4-wire long distance wiring requires a hybrid[2] and is not the subject of this note. (Teleconferencing applications require complex digital hybrids containing acoustic echo cancelling technology.)

What is of concern here is how to add or remove audio from a normal telephone circuit without interfering with the operation of, or being harmed by, the telephone lines.

A *phone patch*, or *phone tap*, is necessary to interface line-level analog audio to and from POTS. The phone patch allows connecting standard audio equipment to a phone line, while isolating the audio equipment from ring tone and line voltage. It operates in parallel with the telephone, with a circuit design that disturbs normal operation very little due to its high impedance input (*if the hold resistor is not needed*).

[1] Duplex means two-way; full duplex is redundant, but, alas, has been misused so long that it is here to stay; half duplex means one-way and is correct usage.

[2] The name comes from the original use of a *hybrid coil* (special transformer) in the telephone whose function was to keep the send and receive signals separated.

[3] 48 VDC was selected because it qualifies as safe low voltage (<50 VDC) in most countries and is easily created from four car batteries wired in series.

[4] The positive terminal is earth grounded to minimize electrochemical reactions on wet telephone wiring. When the wires are at negative potential compared to the ground the metal ions flow from ground to the wire instead of the reverse situation where the metal from the wire migrates causing corrosion.

POTS Characteristics (typical)

Bandwidth	300 - 3.3 kHz (3 kHz BW)
Signal-to-noise	45 dB
Average Level	-9 dBm[†] (275 mV)
Impedance	600 Ω
Connector	RJ-11
Cable	2-Wire (twisted pair)
DC Voltage	48 V[3] (±6V typ)
Polarity	Positive (*tip*, or *green* wire) tied to earth ground[4]; so it measures –48 VDC (relative to ring or red wire).
DC Current	20-26 mA (typ)
DC Resistance	200-300 Ω (typ)
AC Ring Volts & Freq.	90 Vrms, 20 Hz (2 secs on, 4 secs off)

[†] 0 dBm = 1 mW (0.775V) into 600 Ω

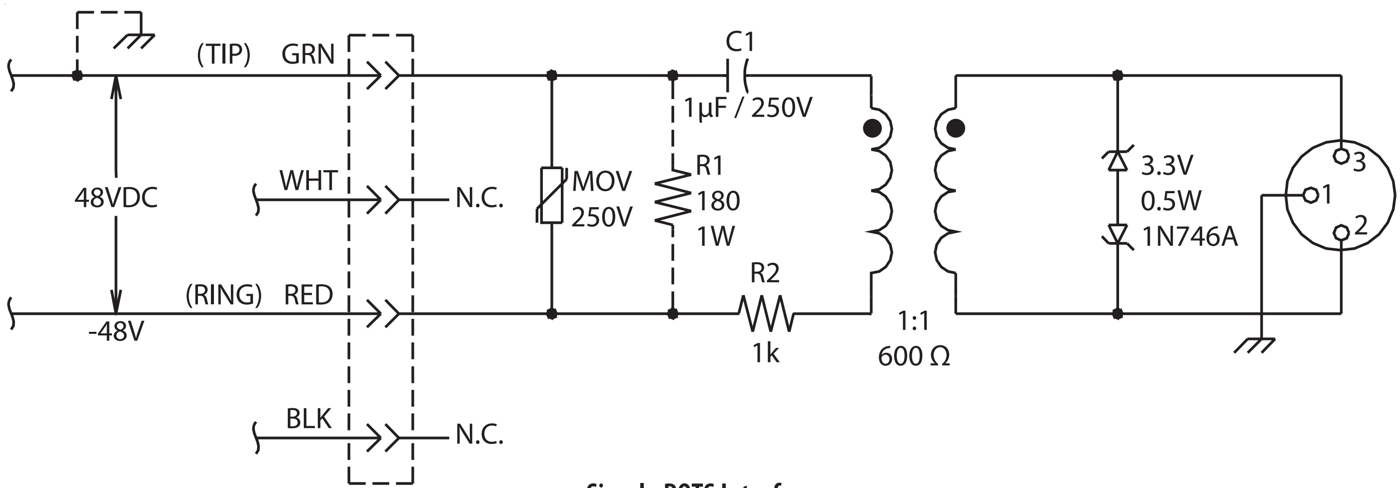
Simple POTS Interface with Cautions

A single transformer and capacitor creates a POTS interface in a pinch; however adding a few more components greatly improves the performance. The transformer provides the necessary isolation, while the capacitor blocks the DC voltage from the transformer.

The diagram shows an enhanced version discussed next:

The MOV (metal-oxide varistor), or any similar transient voltage suppressor, is required due to the extreme lightning-induced voltage spikes that can travel on telephone lines (*thousands of volts*). It needs a maximum operating voltage of at least 250 Vrms. This seems extreme for a 48 VDC powered line, but the telephone company tests their lines by adding as much as another 200 V, so you must guard against worst case.

It is not necessary to add a matching capacitor to the other leg of the transformer primary (to preserve the line balance) as will be seen shortly. Use a non-polar type since the polarity of the DC voltage cannot be guaranteed and oftentimes reverses with different operating modes. The value is not critical and depends on the reflected impedance seen by the series capacitor. Normal usage for this type of phone patch is either to drive a high impedance (≥10 kΩ) input of a recorder or an amplifier, or, if used in the opposite direction (i.e., to add audio to the phone line), driven from a low impedance (≤300 Ω) output. The voltage rating must be high



Simple POTS Interface

enough to withstand the usual DC voltage (and variations) plus the AC ring voltage; a value of 250 Vrms is recommended. Since a 1µF/250V non-polar capacitor can be quite large (and expensive), consider paralleling two or more small non-polar caps (e.g., two 0.47µf/250V, or three 0.33µF/250V rated, etc.).

The resistor, R1, is necessary if the circuit must hold the line, i.e., look-like a phone off- hook. It must be selected to draw enough DC current to drop about 6 V. A big problem comes in predicting this value. The DC source is typically 48 V, but can vary anywhere from 42-54 V, and sometimes *much* more (24-60 V).

Resistor R2 is a good idea to make the line driving impedance higher when using the patch to *add audio* (*total equals R2 + line driver output impedance*).

Luckily when designing a phone patch you do not have to worry much about what the telephone line looks like when the phone is on-hook. This is good because while described as a 600 Ω balanced line, the on-hook line (*the off-hook line is quite different, and will be discussed next*) never measures 600 Ω, nor is it very well balanced. Variations from 500-2500 Ω are reported for the ungrounded side of the line, simultaneous with the grounded side measuring 0-700 Ω – hardly a balanced line. Plus the DC resistance of the telephone cabling is not trivial, easily amounting to as much as 1500 Ω for locations a few miles from the central office (26 AWG is common, measuring 440 Ω/mile).

Once the phone is answered, the system goes into off-hook mode and sends out the dial tone. Now the line is predictable with the balanced output impedance measuring about 400 Ω (±25%), split evenly between the two lines, with the voltage ranging from 42 V to as high as 80 V. Still not well balanced, but a lot closer than the on-hook values.

The back-to-back zener diodes in the secondary clamp any high voltage (including any ring voltage that may appear) that gets through the transformer and protects the downstream equipment. Their value is pretty arbitrary and is determined by what the interfaced unit can withstand. The 1N746s limit the output to 4 V peak-to-peak, or 1.4 Vrms. Likewise the power rating need not be excessive; ½-watt is enough.

Circuit Summary

1. Provide isolation (transformer).
2. Block DC voltage (series capacitor).
3. If required, provide DC path to hold the line (parallel resistor).
4. Provide primary protection (parallel MOV)
5. Provide secondary protection (zener diodes).
6. Protect against too low secondary impedance (series resistor)

DIY (do-it-yourself) Transformer Sources

Telephony has been around for so long that most electronic supply stores carry interfacing transformers (600 Ω to 600 Ω, analog audio transformer with telephone grade frequency response and distortion performance). They come in two types: "wet" and "dry," referring to whether they are designed to pass direct current (DC) – *wet* transformers withstand DC currents without saturating, *dry* transformers do not. For the diagram shown you want a dry transformer, which is smaller and less expensive than wet ones. Most modern telephone circuits use dry transformers.

Three shown, but typical of many:

Bourns Cat. # LM-LP 1001 (thru-hole):
Or SM-LP-5001 (SMT):
www.bourns.com

Radio Shack Cat. # 273-1374 (wire leads):
www.radioshack.com

Tamura Cat. # MET-46 (thru-hole)
www.tamuracorp.com

Other good sources include **Prem Magnetics**
www.premmag.com
and **Midcom**
www.midcom-inc.com

Store-Bought Phone Patch Sources

The following are simple telephone interfaces. They are not *hybrids*. They are used simply to put audio on or take audio off POTS. They are *not for teleconferencing* and will not work due to their lack of acoustic echo cancelling technology. These are for non-conference applications only.

The models differ greatly in features and price, so do your homework before spending momma's hard-earned money.

Comrex Telephone Coupler TCB-2
www.comrex.com

Excalibur HC-1 Handi-Coupler
www.bradleybroadcast.com/2001/telephone.htm

PSC Phone Tap
www.professionalsound.com

Radio Shack
www.radioshack.com