

AN-4 (Midcom TN #98)

LOW COST TELEPHONE LINE INTERFACE (DAA, FXO)

By Joe Randolph, Randolph Telecom, Inc.

March 17, 2005

NOTE: This application note was originally written for Midcom, Inc. and is also posted on their web site at www.midcom-inc.com. An expanded version of this application note is provided in Randolph Telecom's AN-5, "Transformer-Based Phone Line Interfaces (DAA,FXO)," posted on Randolph telecom's web site www.randolph-telecom.com.

Preface

This Technical Note is an update to an earlier Technical Note that was written in 1999. The earlier version was TN #88, "Low Cost, CTR 21 Compliant DAA for Europe." The European regulatory requirement CTR 21 has now been officially withdrawn. Some manufacturers prefer to continue meeting CTR 21, but there is little reason to do so. The design presented in TN #88 can be updated to make it less expensive and also more broadly applicable worldwide.

One of the difficult requirements in CTR 21 was the need for a 60 mA loop current limiter. The current limiter was needed for compatibility with certain older phone line circuits in France. Those lines have now been updated, and the 60 mA current limiter is no longer needed. CTR 21 also imposed an AC impedance requirement that many telecom engineers felt was unnecessarily restrictive.

Since the time that TN #88 was written, there has been considerable relaxation in the regulatory requirements in Europe and other countries worldwide. The result is that the circuit shown in TN #88 can now be simplified to a cost of less than \$2.00 for production quantities of 100,000 annually. At the same time, the number of countries where the simplified design can be used has increased.

Introduction

There are numerous applications where a product must connect to a conventional telephone line. Examples include:

- Telephones
- Modems
- Fax machines
- Set top boxes
- Alarm dialers
- Point of sale terminals
- Remote monitoring and control

When the application is a modem, the phone line interface is typically called a DAA (Data Access Arrangement), while the term usually used for voice applications is FXO (Foreign Exchange Office). The basic functionality is the same, although different performance requirements sometimes apply.

The interface to an analog phone line is primarily an analog circuit function. These days most designers are more comfortable with digital circuit design, so the task of designing a phone line interface can introduce unfamiliar considerations such as isolation, balance, return loss, distortion, echo, power cross, and lightning immunity. Furthermore, most countries impose specific regulatory requirements on phone line interfaces. These requirements are often difficult for uninitiated readers to understand.

This article describes a simple, robust, low cost phone line interface that can be used for a wide variety of applications. As shown in Table 1, the entire circuit has only 30 parts and costs less than \$2.00 for production quantities of 100,00 annually.

The intent of this article is to provide a complete design, including schematic, parts list and layout guidelines, so that even a designer who is inexperienced with phone line interface design can have a good chance of getting it right the first time.

Suitability

The circuit in Figure 1 can be used for many, but not all applications, and it can be used in most, but not all countries. Readers should carefully review this section to determine whether this line interface is suitable for their application.

This design uses a so-called “wet” transformer, which is a telecom term indicating that the DC loop current from the phone line passes through the primary winding of the transformer. In a “dry” transformer circuit, a blocking capacitor is used to prevent DC from passing through the transformer winding, and the DC loop current is diverted through a separate DC holding circuit. Dry transformer circuits are slightly more expensive than wet transformer circuits, but eliminating the DC current from the transformer winding allows the transformer to be much smaller. A dry transformer design also allows further enhancement of performance parameters such as impedance matching and linearity, which can be important for certain applications.

Wet transformer circuits are simple and inexpensive, but they have some limitations. The DC loop current, which typically ranges from 20 to 100 mA, must be tolerated by the transformer without causing the core to saturate. This is accomplished by using a comparatively large transformer core and gapping the core to prevent saturation. As a result, wet transformers tend to be larger than their dry counterparts, and their shunt inductance is much lower. The lower shunt inductance makes impedance matching more difficult, and the silicon steel typically used for the core material places limits on the distortion performance.

However, the extremely low cost and the high reliability of the wet transformer circuit make it the perfect choice for some applications. In fact, wet transformer circuits typically offer the lowest possible cost and highest reliability of any available technology for phone line interfaces. Because of these attributes, a wet transformer design should be used as the default choice unless certain product requirements render it unsuitable. Following are the key considerations where a wet transformer design would **not** be suitable:

Size

Wet transformers are typically larger than their dry counterparts. The Midcom 82111 transformer used in this design has a footprint of .908 by .945 inches (about 23 mm by 24 mm), and is .490 inches tall (about 13 mm). This may not be acceptable for applications with severe space constraints.

Impedance Matching for Certain International Applications

The AC impedance presented to the phone line (usually measured as the parameter “return loss”) is subject to regulatory requirements in some countries. There are no longer any regulatory requirements for return loss in North America or the European Union, but some countries continue to have requirements for this parameter. The wet transformer design presented here meets the requirements for most countries, but Australia, Brazil, India, and South Africa are some notable exceptions. In China, the return loss of the wet transformer design meets the regulatory requirements for modems and fax machines, but not for voice equipment.

Distortion for Certain Modem Applications

This wet transformer design is not suitable for high speed, full duplex modems that use echo cancellers. Echo canceling modems such as V.32, V.34 (full duplex mode), and V.90 require extremely low transmit distortion that is more easily achieved with a suitable dry transformer.

However, the wet transformer design presented here will work very well for conventional split band modems such as V.21 (300 bps), V.22 (1200 bps), and V.22bis (2400 bps). It will also work well for any fax modem, including V.34 (33,600 bps), since fax modems are half duplex and do not use echo cancellers.

Summary of Applicability Considerations

In summary, the low cost design presented here is suitable for applications where the requirements for transformer size, AC impedance matching, and distortion are within the limits imposed by the use of an inexpensive wet transformer. All of these limitations can be overcome by using a dry transformer circuit, but the dry transformer circuit adds about 50 cents in cost and is more complicated to design.

Circuit Description

Referring to Figure 1, the central element of the line interface is T1, the Midcom 82111 transformer. T1 is used to couple the analog transmit and receive signals across the isolation barrier.

U3 is a solid state relay that will put the interface in the active, offhook state when the /OFFHOOK input is pulled low, closing the relay. Note that the /OFFHOOK control line must sink about 6 mA in the active-low state, and that it must be pulled to +5V when the interface is in the idle, onhook state.

Opto isolator U2 is connected so that the output /RINGDET will produce a pulse train of negative-going pulses when a ringing signal of more than 20 VRMS is applied to tip/ring. The pulse train will have the same frequency as the applied ringing signal (typically 15 to 55 Hz).

The output signal on /RINGDET can have slow edges, and for ring signals in the range of 10 to 20 VRMS the logic low levels will be invalid. For these reasons, the /RINGDET signal should probably be polled rather than connected to an interrupt. To avoid false ring detection caused by transients on

tip/ring, the software that reads the /RINGDET output should debounce the signal by looking for three consecutive transitions that fall within the range of 15 to 55 Hz.

Surge protector E1 protects against lightning surges and overvoltages that appear across tip/ring. Diode D1 clamps any residual energy that couples through the transformer.

Fuse F1 is generally required in the USA and Canada to pass the M1 overvoltage test in UL/CSA 60950. This fuse is not required in other countries, and under certain circumstances it is not required for UL/CSA 60950. Any fuse used in this location should open cleanly for the M1 test in UL/CSA 60950, and should tolerate lightning surges of 100 amps peak, 10x1000 uS duration. The fuses listed in the bill of materials meet these requirements, but there are several alternative choices including some in surface mount form.

The LMV822 op amp U1A provides the transmit driver for analog transmit signals, and U1B provides the receive amplifier. Note that the LMV822 has a rail-to-rail output stage that can drive 600 ohm loads, which is an important feature for the transmit driver. Any substitutions for the LMV822 should be made with this requirement in mind.

The transmit and receive gains are set to 0 dB. This means that signals applied between ground and TRANSMIT will appear with the same amplitude across a 600 ohm load on tip/ring, and signals applied across tip/ring will appear with the same amplitude between the RECEIVE output and ground. Note that there is a 2.5 volt DC bias on the RECEIVE output, so a DC blocking cap may be needed if the input connected to the RECEIVE output requires a different DC level.

Resistor R4 sets the nominal AC impedance presented to tip/ring at 600 ohms. Resistor R10 provides a modest amount of cancellation of the transmit signal from the receive signal. Any changes made to the receive gain will require a re-optimization of the value for R10.

Layout Guidelines

- 1) The isolation barrier shown by the dotted line is a key requirement for regulatory compliance. This barrier can be visualized as a keep-out “moat” around the tip/ring circuits, with only T1, U2, and U3 bridging the moat. Aside from these three isolation devices, there should be no components, circuit traces, or copper on any layer inside the isolation barrier.
- 2) Note that the isolation barrier must be maintained in three dimensions. This means that conductive parts associated with the equipment housing or with other circuit boards should not be placed directly above or below the tip/ring circuits in violation of the isolation barrier distance.
- 3) The width of the isolation barrier can be as small as 1.6 mm and still meet regulatory requirements, but a 5 mm barrier will provide better protection against common mode lightning surges, which can reach 5000 volts in some applications.
- 4) The tip/ring circuits inside the isolation barrier should be grouped together on a small island that is separated from all other circuitry by the isolation barrier.
- 5) The trace width used for the circuits on the tip/ring side of the isolation barrier should be a minimum of 0.5 mm (15 mils) to handle lightning surges. This value assumes the use of standard 1 ounce copper for the circuit board.

- 6) Standard analog design practices should be used for the layout of the circuits around the LMV822 op amp. These include short traces for the inverting and non-inverting inputs, good power supply decoupling, and a low noise power supply. An internal ground plane in this area is desirable but not essential.

Possible Enhancements

The circuit shown in Figure 1 is a simple, low cost, and rugged phone line interface. Following are some changes that could be considered for different applications:

+3.3 Volt Operation

The circuit of Figure 1 will operate on a 3.3 volt supply, but the output swing available across a 600 ohm load on tip/ring will be reduced to about 1.6 volts peak to peak (down from 2.5 volts peak to peak with a +5 volt supply). This amount of swing is adequate for transmitting V.21 and V.22 modem signals at the allowable maximum of -10 dBm, but V.22bis data modems and V.29, V.17, and V.34 fax modems have peak-to-RMS ratios that require greater swing. These modems should be limited to a maximum transmit level of -13 dBm if a single +3.3 volt supply is used. If higher transmit levels or lower supply voltages are desired, the transmit driver in Figure 1 can be converted to a differential driver by adding another op amp. This effectively doubles the available output swing.

Loop Current Detection

In some applications, it is necessary to detect the presence or absence of DC loop current from the central office. For instance, a brief interruption of central office loop current is often used to signal that the far end party has hung up. For voice messaging equipment, detection of this signal can be used to quickly return to the idle state after an incoming message has been completed.

To add loop current detection to the circuit of Figure 1, an opto isolator can be inserted so that a portion of the loop current flows through its input LED. Care must be taken to ensure that the LED in the opto isolator is adequately protected from surge currents, but there are several possible circuits that will accomplish this.

Caller ID and On-Hook Monitoring

Many applications require some method for monitoring the voiceband AC signal that is present on the phone line during the on-hook state. Examples include caller ID reception, and detection of the CNG tone for automatic voice/fax switching.

For implementing this feature, it is highly desirable to couple the received signal through the transformer. This allows the transformer to provide both lightning protection and immunity from common mode 60 Hz interference. These two impairments often present problems for on-hook monitor implementations that use capacitively coupled differential amplifiers.

It is possible to use the transformer to couple the signals in the on-hook state by placing a bypass capacitor across the switchhook relay and making some other minor modifications to the circuit of Figure 1. Care must be taken in the design of such circuits to avoid affecting compliance with other regulatory requirements such as on hook AC impedance. The options that can be considered will depend on whether the monitoring is only for caller ID signals or is for other signals such as CNG tones.

High Speed, Full Duplex Modems (V.32, V.32bis, V.34, V.90, and V.92)

The circuit of Figure 1 will provide excellent performance for low speed full duplex data modems up to 2400 bps, and for half duplex fax modems up to 33.6 K bps using V.34 modulation. These modems have only modest requirements for distortion in the DAA, which allows the use of a very inexpensive transformer.

Unfortunately, this circuit is not well suited for high speed, full duplex data modems. The principal limitation with high speed full duplex modems is that they use echo canceling techniques that are very sensitive to distortion in the transformer.

For high speed modem applications, the design should be converted to use a suitable dry transformer and an appropriate DC hold circuit.

Compliance With Worldwide Regulatory Requirements

As explained in the section on suitability, the circuit shown in Figure 1 can be used in most, but not all countries. The only parameter that prevents the wet transformer from being used in certain countries is the AC impedance presented to the phone line (typically specified as return loss).

If the application requires a single design that can be used in any country worldwide, the design must be converted to use a suitable dry transformer and an appropriate means for selecting the desired AC impedance.

Smaller Size

The circuit of Figure 1 uses a fairly small amount of board area (about 1.5 square inches or 10 square cm), but the height of the 82111 transformer makes it unsuitable for some space-constrained designs. For such applications the circuit can be converted to use a miniature dry transformer such as the Midcom 671-8489. The resulting design using the 671-8489 occupies about one square inch of board area while maintaining a maximum component height of less than .177 inches (about 4.5 mm).

About the Author

Joe Randolph is a consultant who specializes in the design of telecommunications equipment. He has extensive experience with the design of analog and digital PSTN interfaces for worldwide applications,

and has product designs approved in over 100 countries. His experience with product design includes telephones, modems, voice messaging equipment, fax machines, PBXs, central office line cards, T1/E1, DSL, and internet telephony (VOIP) equipment. If you have questions about the circuit described here, or if you want assistance with a related application, you can contact Mr. Randolph directly:

Joe Randolph
Randolph Telecom, Inc.
Phone: 781-721-2848 (USA)
Email: jpr@randolph-telecom.com
Web Site: <http://www.randolph-telecom.com>

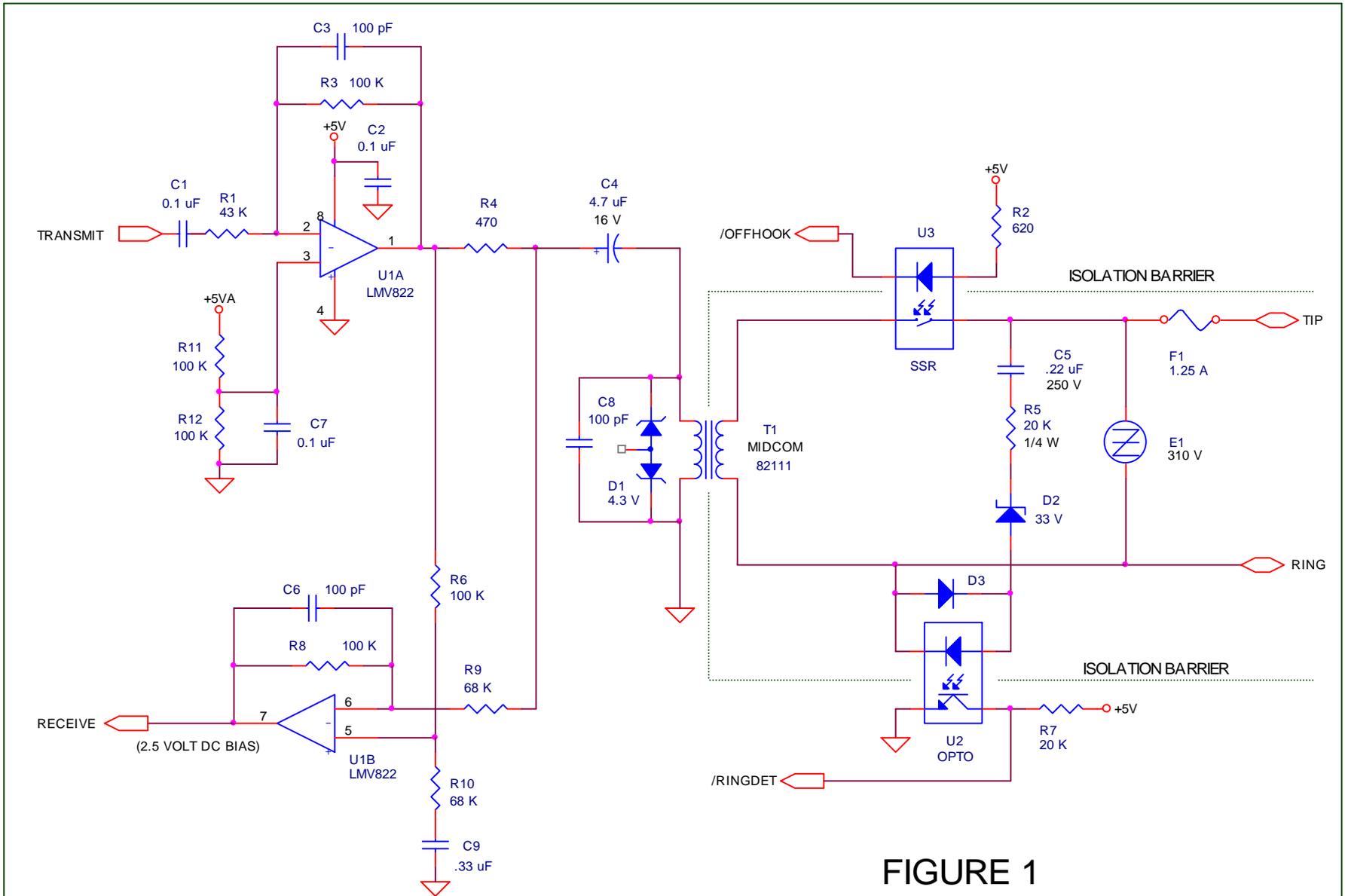


FIGURE 1
BASIC PHONE LINE INTERFACE CIRCUIT

TABLE 1
DAA/FXO CIRCUIT COST ESTIMATE
(100K QUANTITY)

Quantity	Reference Designation	Description	Vendor	Unit Cost	Ext. Cost
3	C1,C2,C7	Ceramic cap, 0.1 uF, 25 V, Z5U	Generic	0.03	0.09
3	C3,C6,C8	Ceramic cap, 100 pF, 25 V, NPO	Generic	0.03	0.09
1	C4	Aluminum cap, 4.7 uF, 16 V	Generic	0.03	0.03
1	C5	Ceramic cap, .22 uF, 250 V, Z5U	Generic	0.15	0.15
1	C9	Ceramic cap, 0.33 uF, 25 V, Z5U	Generic	0.05	0.05
1	D1	Bidirectional zener, 4.3V, CMPZDA4V3	Central Semi	0.09	0.09
1	D2	Zener diode, 33V	Generic	0.05	0.05
1	D3	Signal diode	Generic	0.03	0.03
1	E1	Thyristor, 310V, TISP4350H3	Bourns	0.19	0.19
	E1 Alternate	Sidactor, 310V, P3100SC	Littelfuse		
1	F1	Fuse, 1.25 amp, 230-1.25	Littelfuse	0.10	0.10
	F1 Alternate	Fuse, 1.25 amp, C515-1.25	Bussmann		
1	R1	43 K, 5%, 1/10 W	Generic	0.01	0.01
1	R2	620 ohm, 5%, 1/10 W	Generic	0.01	0.01
5	R3,R6,R8,R11,R12	100 K, 5%, 1/10 W	Generic	0.01	0.05
1	R4	470 ohm, 5%, 1/10 W	Generic	0.01	0.01
1	R5	20 K, 5%, 1/4 W	Generic	0.01	0.01
1	R7	20 K, 5%, 1/10 W	Generic	0.01	0.01
2	R9,R10	68 K, 5%, 1/10 W	Generic	0.01	0.02
1	T1	Transformer, Midcom 82111	Midcom	0.25	0.25
1	U1	Op amp, LMV822	National Semi	0.25	0.25
1	U2	Opto-isolator, SDT400-B	Solid State Optronics	0.06	0.06
1	U3	Solid-state relay, AD6C111	Solid State Optronics	0.42	0.42
	U3 Alternate	Solid state relay, PS7341CL-1A	NEC		
30	Total Parts Count		Total Parts Cost:		\$1.97