73M2901CE
V.22 *bis* Single Chip Modem

APPLICATION NOTE

AN_2901_014 **JULY 2005**

73M2901CE Line-In-Use / Parallel Pick Up Detection

Introduction

The 73M2901CE integrated circuit modem provides all the microprocessor control, modulation, and demodulation functions required to implement a V.22 *bis* 2400 bps modem. Embedded modems can be found in a wide variety of products. In consumer products built for a residential environment, it is very likely that the modem will share the same phone line as the household's main phone or fax equipment. The embedded modems are typically considered a lowest priority device and should never take the line if other equipment is already using it. The feature of detecting whether the line is being used before the modem attempts to call is referred to as "Line-In-Use" detection. Expanding on this concept, if an embedded modem is already connected, it should be able to detect when another device attempts to place a call and must release the line. The feature of detecting the call attempts while off hook is referred as "Parallel Pick Up" detection or "911 detection" since this capability prevents the device potentially blocking an emergency call. When the modem has released the line, the other calling equipment (phone or fax) will need to hang up to get a dial tone, but the line is free again for the user to make a call.

Different techniques have been proposed to reliably support those two features; they are all based on the detection of the modified characteristics of the phone line when a device is attempting a call and therefore has seized the line. Those characteristics are the line voltage, the line AC impedance and the energy present on the line. All those parameters will be modified when a device connects to the phone line and could potentially be used to determine the line status. In addition, the detection that takes place for the Line-In-Use condition, prior to placing the call, must have as little effect on the line as possible since it could potentially corrupt the on-going call, e.g., modem communications, if another device is on the line.

DC line voltage drops when a device seizes the line. From a typical 48V value, the Tip/Ring voltage will fall to 5 to 15V. Provided there are ways to reliably detect whether the voltage is above or below a threshold of say 18V, this should represent a reliable way to determine the Line-In-Use status of the line. The typical 48V found in the USA. can actually range from 36V to 56V elsewhere. Although a convenient and reliable method in applications in the USA, the 18V threshold cannot cover all situations for a worldwide design where telephone line characteristics can vary. Today there are fewer cases where this will not work now that all countries use a current limited feed to the network, but it is important to be aware there could be places where 18V is not appropriate.

Monitoring line voltage is a convenient way to detect the line status for Line-In-Use detection, but this will not work for Parallel Pick Up. Once a call is in progress, the voltage drop change caused by another device will not be nearly as great as when the line was not in use. This is the situation when Parallel Pick Up detection is being attempted. Another method must be used to support this feature.

The phone line AC impedance is also modified by a second parallel device and could be used to determine the line status. However the wide range of possible line impedances makes this approach difficult to set up and so this technique will not be considered for the Line-In-Use feature. Nonetheless this impedance modification can be efficiently used for Parallel Pick Up detection. The DC level of the off hook equipment interface is a function of the source DC current limit, the losses in the network due to the DC resistance of the line to the line interface of the receiving modem, and the DC resistance present in the load across Tip and Ring, typically 100Ω to 200Ω. If other equipment in parallel seizes the phone line, the overall impedance will be lowered (in theory 50Ω if 100Ω||100Ω) resulting in a DC voltage drop at the interface. This drop can be detected by the modem and translated into a Parallel Pick Up event. Since the initial and parallel impedance can vary over a wide range, a fixed threshold would not be sufficient. There are ways to address this problem, however.

Finally, the third characteristic that can be translated into a line status change is signal energy. The telephone network is generally set up to work with a characteristic AC impedance of 600Ω. If another device with 600Ω impedance suddenly appears on the line, the AC signal will now be across a 300Ω load and will in theory drop 6dB in amplitude. This should be detectable if the amplitude is being monitored, which is the case in any modem.

From the above summary it is clear that the solution needed to support Line-In-Use and Parallel Pick Up detection is trivial. To cover all the requirements under all the conditions, a number of hardware and software techniques can be used. The best solution in a particular application will be a trade off between performance, reliability and cost.

73M2901CE Implementation

The Teridian 73M2901CE supports all types of Line-In-Use and Parallel Pick Up detection. Below is a list of those options. Each of them is user selectable, i.e., it is possible to completely disable the function, select one option among the functions, or select all the options for the function.

Line-In-Use Detector

- Tip/Ring voltage sensing
- Quiescent Line qualification
- Active following an ATD.. command prior to seize the line
- Check for dial tone after going off hook but before dialing
- No line seizure will occur when LIU is detected and a special result code is returned to the Host

Parallel Pick Up Detection

- DC current loop sensing.
  Active when the 73M2901CE is off hook.
- Incoming carrier level drop sensing.
  Active when the 73M2901CE is off hook and connected.
- The line is released when PPU is detected and a special result code is returned to the Host.

Line-In-Use Detection

The 73M2901 CE provides two different methods to detect the status of the line prior to attempting a call. Those options can be combined together or selected individually.

Tip/Ring Voltage Sensing

This method of detection determines whether the voltage on the line is above or below a preset value. This preset value being user selectable through a Zener diode. Usually the external circuitry needed for such detection cannot remain permanently on the line; thus an external switch is required to turn the function on or off. To support that switch, the 73M2901CE uses one of its GPIO, USR10.

Figure 1 shows a typical circuit for sensing the DC voltage across the network. By turning on U2 the voltage is applied across the reference circuit consisting of D2 and R5. If the line voltage is greater than the Zener voltage, U3 will be activated and the LIU OUTPUT will go low, if not the output will remain high. For the 73M2901CE, S89 bit 5 should be set when using this circuit to invert the sense of the detector. This inversion makes the use of a single optocoupler possible for LIU, PPU, line reversal, and ring detection.

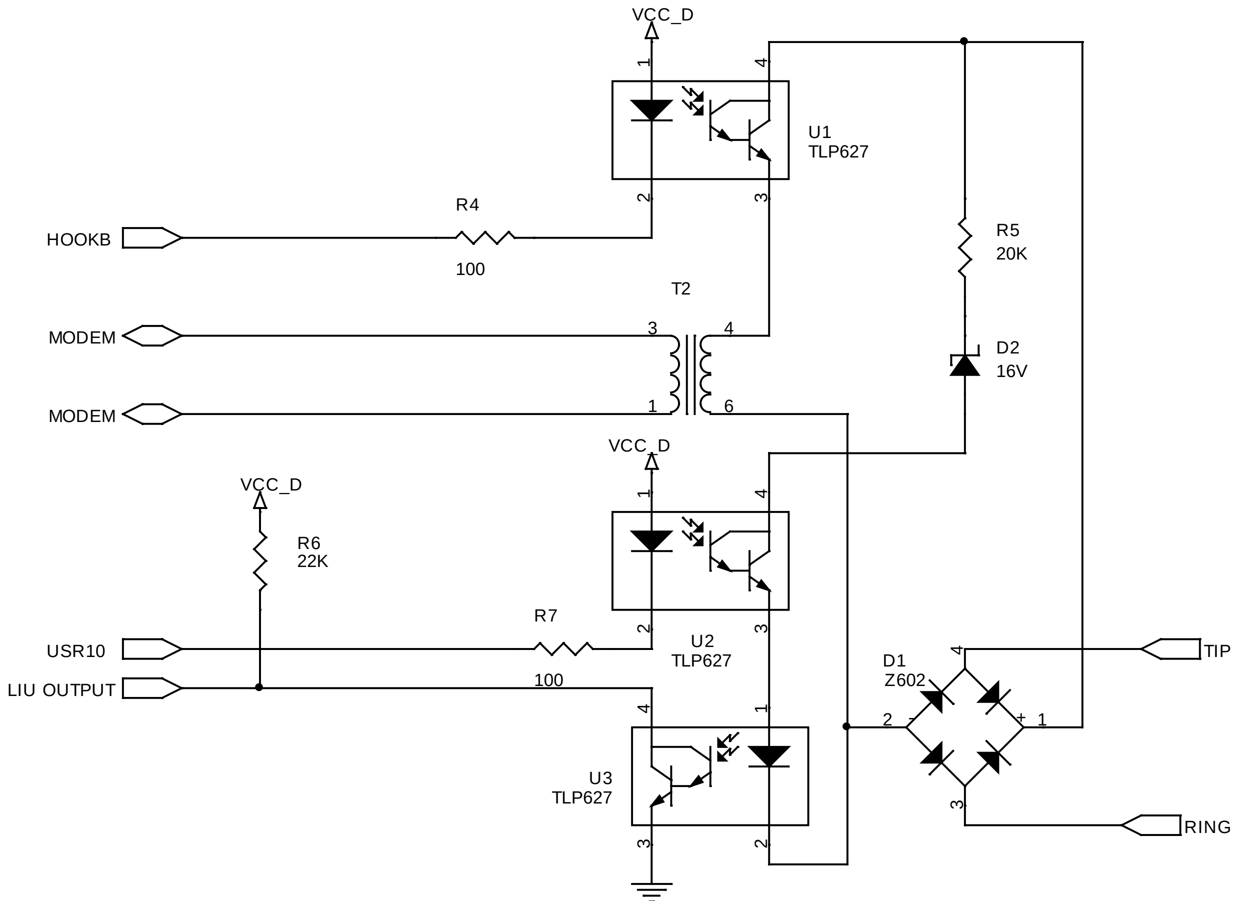


Figure 1: Typical LIU Voltage Sensing Schematic for the 73M2901CE

Several S register bits can be used to modify the timing, and enable LIU-V sensing. S110 and S111 enable LIU-V, USR10 and adjust the wait timing for LIU-V operation.

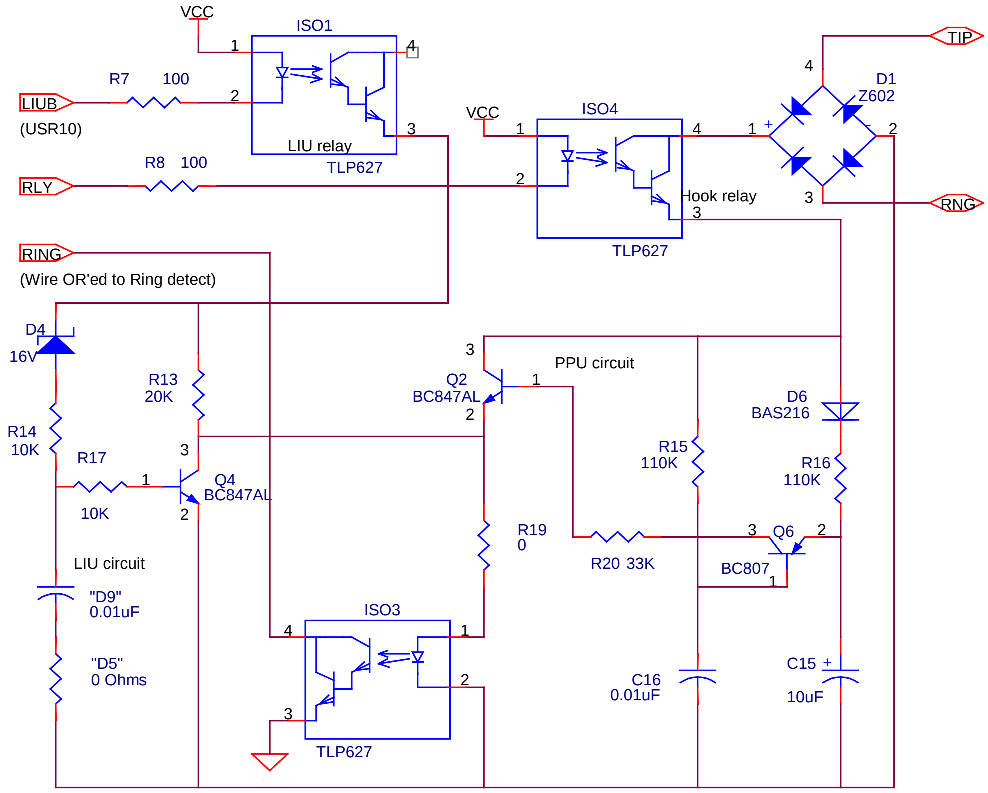


Figure 2: ***Typical LIU and PPU Voltage Sensing Schematic for the 73M2901CE***

Quiescent Line (Energy) Detection

An alternative way of detecting the Line-In-Use status is to check for signal energy on the phone line. Assuming that any communication already in progress generates some energy on the line, the 73M2901CE is able to qualify the presence or absence of energy above or below a selectable threshold and for a selectable amount of time. If energy is detected, it will be assumed that the line is in use and a result code will be returned to the host processor. To support that option, the modem must be able to "listen" into the phone line; this is achieved through the Caller ID circuitry if present or through some similar circuitry added for this purpose. Once again, if the design has to drive an external switch to activate this circuitry, the 73M2901CE is able to dedicate one of its GPIO, USR10, to that function. Register S110 bit 2 enables LIU-E mode and S112 and S113 adjust the timing and threshold. It is not necessary to do this is the AC impedance is high enough. To meet EIA 777A this impedance is 60kΩ. An external R/C across the hook switch can be used to do this in many cases. The 73M2901CE have a 20dB gain boost that can be used to make up for the losses in this R/C. This is on by default. A typical circuit is shown in Figure 3. There are several variations for this depending on the topology of the DAA.

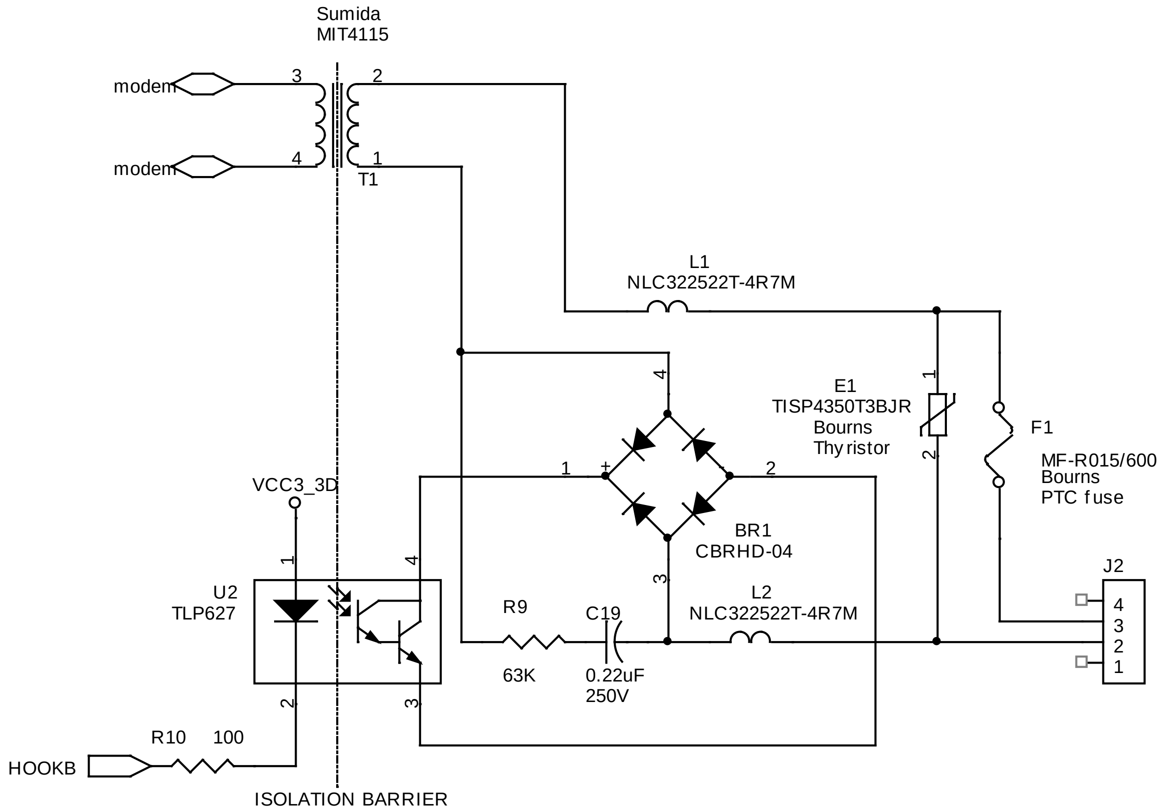


Figure 3: DAA Showing the Energy LIU (Caller ID) Circuit

If there are other components such as diodes or transistors that must be turned on for the signal path to be active, they must also be bypassed as well. In Figure 3 only the opto-transistor and bridge rectifier need to be bypassed by R9 and C19. Figure 6 shows a complete DAA with all the various detector features supported. In this case two R/C paths, R42, C25 and R43, C26, are needed because other circuitry must be bypassed.

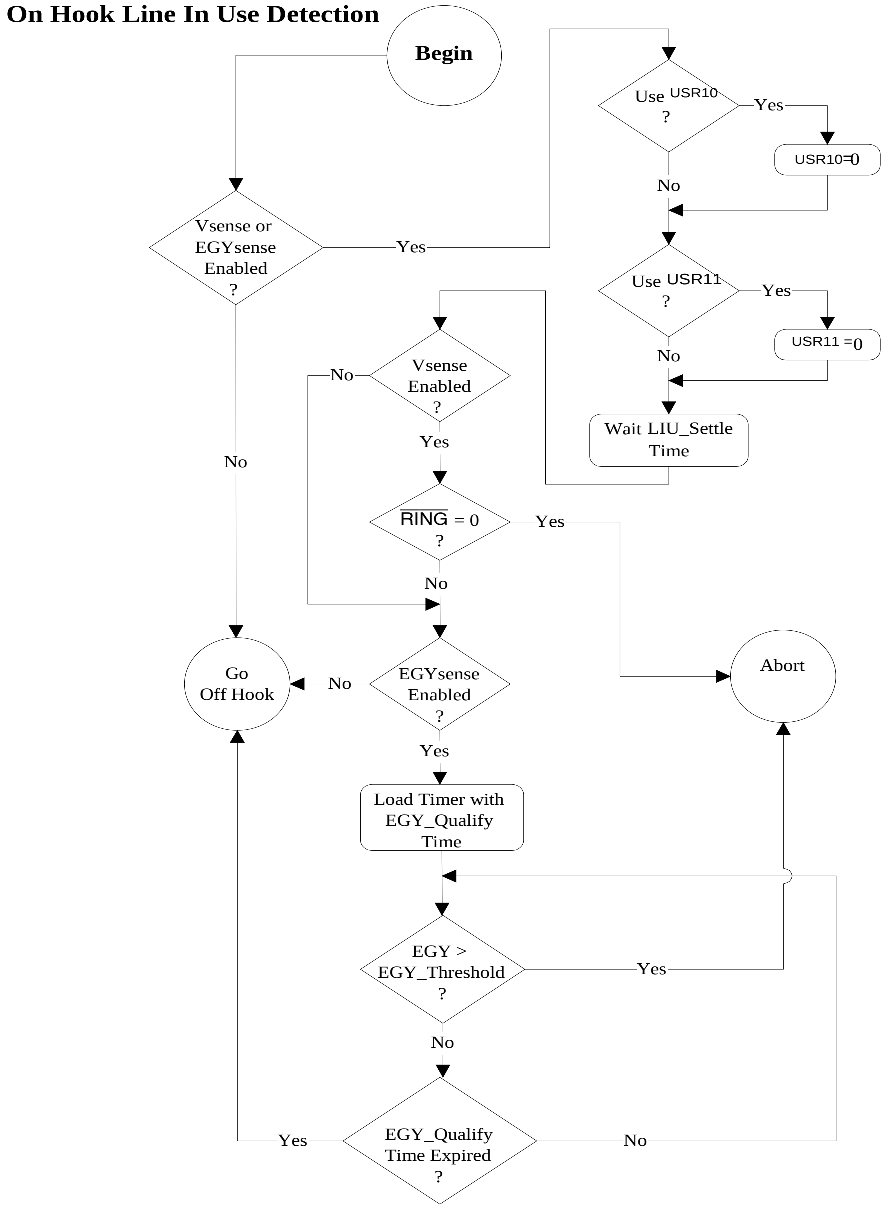


Figure 4: Line-In-Use Detection Flowchart

73M2901CE Configuration (Line-In-Use)

The configuration of the 73M2901CE LIU is handled through a set of registers.

S110	**Line-In-Use / Parallel Pick Up**	
Default	70h	LIU and PPU disabled.
0	Bit 0	Enables Voltage sensing Parallel Pick Up detection (PPU-V).
0	Bit 1	Enables Voltage sensing Line In Use detection (LIU-V).
0	Bit 2	Enables Energy sensing Line In Use detection (LIU-E).
0	Bit 3	Enables Call-Waiting Caller-ID option. This bit applies only to Off-Hook/Online/Type II Caller-ID.
1	Bit 4	Enables HiZ TXAN/TXAP while looking for CID.
1	Bit 5	Enables RxGain (20 dB) while looking for CID.
1	Bit 6	Enables USR10 to activate LIU circuitry.
0	Bit 7	Long space disconnect enable.

S111	**Line In Use Voltage Settling Time**	
Default	20	200ms
	D0-D7	0-254 in 10ms units
	This sets the timing after which $\overline{\text{RING}}$ is read. The state of the external circuitry will not be considered valid till the settle time has elapsed.	

S112	**Line In Use Energy Detection time**	
20	Default	2 seconds
	D0-D7	0-254 in 100ms units
	This register sets the duration during which the energy on the line must remain below the set threshold in S113.	

S113	**Line In Use Energy Detection Threshold**	
Default	60	Range from 0-95
	Sets the threshold for the Line In Use energy detection. A lower number sets a higher-level threshold.	

ATS110+2 enables the voltage sensing Line In Use detection. In this option the USR10 enable must also be set to use this function and the user may set the settling time (S111).

ATS110+4 enables the energy sensing Line In Use detection. In this option, the user may also set the validation time (S112) and energy threshold (S113).

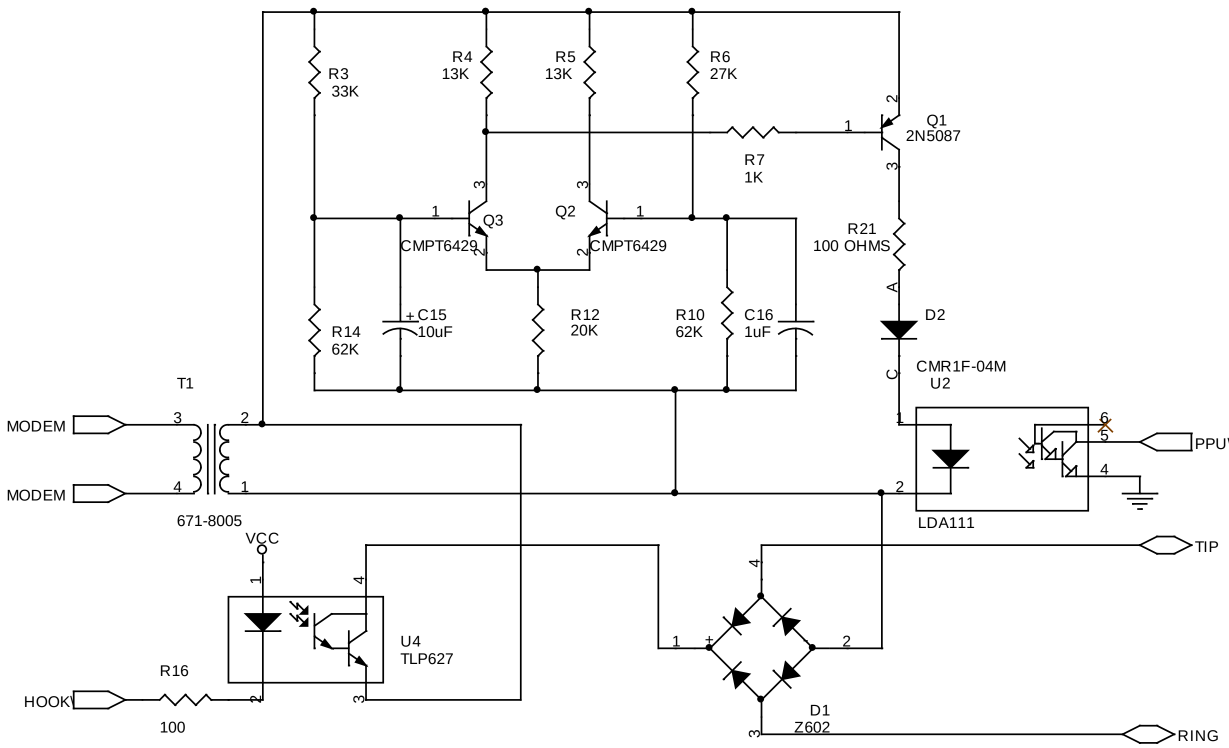
Example:

ATS110+2S110+64 sets the 73M2901CE to perform a voltage sensing on the line using USR10 as the external switch driver immediately after an ATD… command has been issued.

Parallel Pick Up Voltage Detection

The 73M2901CE supports two methods of detecting Parallel Pick Up. It is not feasible to use the same method for Parallel Pick Up Voltage threshold detection that was used for sensing Line-In-Use detection. But it is possible to use the voltage drop that occurs when a parallel phone if the change can be sensed and used to provide detection.

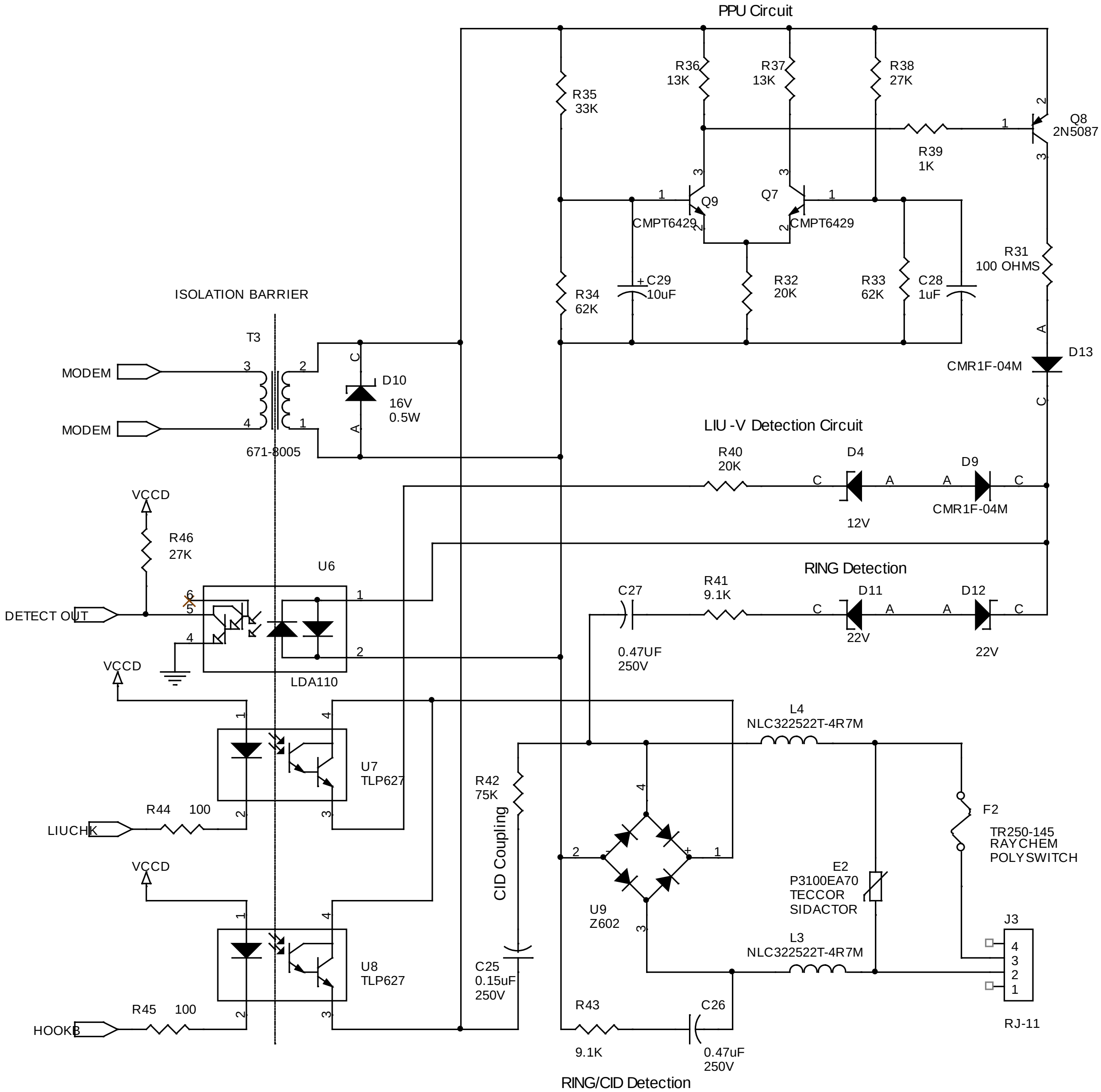
Figure 5: Typical PPU-V Circuit Schematic



The methods for detecting another device picking up when an automated telecom device already is in a session usually involves detecting the change in voltage caused by the other device “stealing” current. Since the telephone company supplies a constant current, if two devices are off hook at the same time the voltage will be lower than if only one is off hook. The problem is that the current supplied by the telephone company can vary from 20 to 100 mA and the impedance of the telephone devices can also vary widely. A method of sensing the off hook voltage and “storing “ it for future reference needs to be used. The easiest way is to use a capacitor to store a reference voltage and then sense whether the voltage suddenly drops. Figure 5 uses a differential transistor pair, Q2 and Q3, to sense a proportion of the off hook voltage set by the ratio of R3/R14 stored on a large (10uF) capacitor C15 connected to the base of Q3. On the base of the Q2 the reference is set to a voltage slightly higher determined by the ratio of R6/R10 and stored on a smaller capacitor, C16 (1uF). This assures the pair always bias up with Q2 turned on and Q3 turned off. The collector of the Q3 transistor is connected to a buffer, Q1, to drive a low current optocoupler. If another device goes off hook in parallel with the detector, the voltage on the smaller capacitor can change more quickly than the voltage on the larger capacitor, causing Q2 to turn off and Q3 to turn on. This turns on the buffer to the optocoupler input and puts out a negative pulse on the detector’s output. The duration of the pulse is the time it takes for the differential pair to return to their original on and off condition. This circuit must always see the correct polarity for the DC voltage, so it must reside inside the diode bridge along with other polarity sensitive components.

A single optocoupler can be used for the combined output of the ring detect, Line-In-Use, and parallel pick up as shown in Figure 6.

Figure 6: Typical Application Combining Caller ID, Line-In-Use Detection and Parallel Pick Up Detection Circuit



73M2901CE Configuration (Parallel Pick Up)

The 73M2901CE has register S89 to change the polarity of the PPU and LIU signals and for Parallel Pick Up Energy detection. For operation with the recommended 73M2901CE hardware circuitry, S89 should have bit D5 set to 1.

S110 Line In Use / Parallel Pick Up		
Default	70h	LIU and PPU disabled
0	Bit 0	Enables Voltage sensing Parallel Pick Up detection.
0	Bit 1	Enables Voltage sensing Line In Use detection.
0	Bit 2	Enables Energy sensing Line In Use detection.
0	Bit 3	Enables Call-Waiting Caller-ID option. This bit applies only to Off-Hook/Online/Type II Caller-ID.
1	Bit 4	Enables HiZ TXAN/TXAP while looking for CID.
1	Bit 5	Enables RxGain (20 dB) while looking for CID.
1	Bit 6	Enables USR10 to activate LIU circuitry.
0	Bit 7	Enables USR11 to activate LIU circuitry.

ATS110+1 enables the Parallel Pick Up Voltage detection. A low level on the $\overline{\text{RING}}$ input while the 73M2901CE is off hook will cause the modem to release the line.

Example:

ATS110+1 sets the 73M2901CE to perform Parallel Pick Up detection while off hook.

Parallel Pick Up Energy Detection

Energy detection is enabled through register S89 bit 3 (S89+8) for the 73M2901CE. Energy detection is actually done by monitoring the modem's AGC level, which I already done during the modem's demodulation process. When PPU-E is enabled and a drop greater that the value programmed into register S116 is detected, the modem will go on hook. This is only available while the modem is in a connected state since the demodulator must be active. Slow changes in the receive level can be compensated for by the AGC, but a sudden drop in level signifies a parallel device may have gone ff hook. No special hardware is required for this to work, so any modem configuration can support this feature without any modifications.

S89	**Parallel Pick-up Detection/ Fast Connect (Default=0)**		
	0	PPU disabled	
	Bit	Value	
	Bit 1,0	00-11	N command value.
	Bit 2	0	Reserved.
	Bit 3	1	PPU Energy (PPU-E) detection enabled.
	Bit 4	1	Reverses ring input polarity for PPU-V (Default is RingB active low for PPU-V).
	Bit 5	1	Reverses ring input polarity for LIU-V (Default is RingB active low for LIU-V).
	Bit 6	1	Fast connect originate handshake when specifying Bell 212. Will send FLAGS as part of the handshake when Y1 or Y4 is selected.
	Bit 7	1	Reserved.

S116	**Parallel-Pick-Up Energy Detection Threshold**	
	n	72, 80, 90.
3	72	1 db energy loss threshold.
	Value	Energy loss detected.
	72	1 dB loss of energy detection.
	80	2 dB loss of energy detection.
	90	3 dB loss of energy detection.
	This register sets the threshold for PPU to detect loss of energy compared to the energy level at the time of connection.	

As this application note describes, there are many optional ways to support the advanced features line monitoring provides. Modems that support line monitoring provide additional safety for the end user since the modem will not occupy the line in an emergency situation. The 73M2901CE provides the designer with choices in how there features can be supported. These features have been used in many applications and have been proven to be effective and reliable.