EVBD-ACPL-C87B/C87A/C870

Isolated Voltage Sensor Evaluation Board

User Guide

Board Description

The ACPL-C87x evaluation board (see Figure 1 and Figure 2) is designed to support the evaluation of the ACPL-C87x precision optically isolated voltage sensors. The ACPL-C87x series is available in three choices: ACPL-C87B (±0.5% gain tolerance), ACPL-C79A (±1% gain tolerance) and ACPL-C790 (±3% gain tolerance). Featuring 2 V [1] input range and 1 GΩ high input impedance, these isolation amplifiers are specifically designed for voltage sensing in electronic power converters applications, including motor drives and renewable energy systems. The ACPL-C87x is identified as U1 on the evaluation board.

On the input side of the evaluation board, power terminals P1 and P2 are provided for incoming voltage connection. This voltage is required to scale down to suit the input range of the voltage senor. This can be achieved by choosing appropriate resistors and mount on the footprints provided for R1 through R3. On the output side of the evaluation board, header connector P7 provides a connection port for power supply to the board and signal interface with next stage such as an analog to digital converter or a signal processing and control device.

Note:

1. The ACPL-C87x data sheet specifies 2 V as the nominal input range. Full scale input range (FSR) is 2.46 V.

Figure 1. The ACPL-C87x evaluation board (top view)

Features

- User-configurable voltage sensing range up to 1230 V
- Single 5 V supply or dual supply up to ±15 V
- Onboard offset calibration
- Onboard isolated 5 V power supply for high voltage side
- User-controllable shutdown

Voltage Sensor Applications

- Isolated voltage sensing in AC and servo motor drives
- Isolated DC-bus voltage sensing in solar inverters, wind turbine inverters
- Isolated sensor interfaces
- Signal Isolation in data acquisition systems
- General purpose voltage isolation

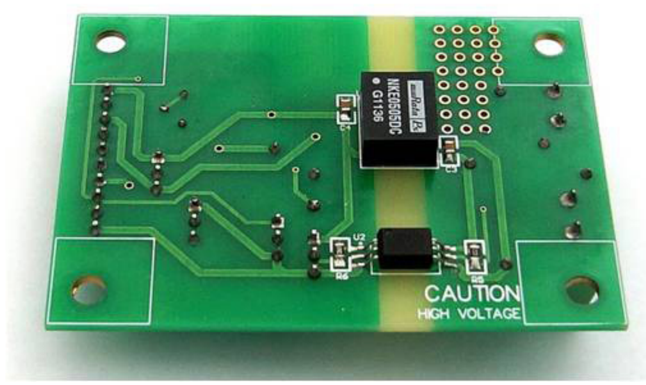

Figure 2. The ACPL-C87x evaluation board (bottom view)

Schematic

Figure 3 shows the evaluation board schematic. In a typical voltage sensing implementation, a resistive voltage divider is used to scale the DC-link voltage to suit the input range of the voltage sensor. Power terminals P1 and P2 are used to connect to the DC-link voltage across nodes L1 and L2 to be monitored. This voltage, denoted as V_{L1} as L2 is connected to the reference point GND1, is scaled down through a resistive divider consists of resistors R1 through R4 in series. On this board, R4 has a fixed value of 10 kΩ, although it can be replaced by another value, if desired.

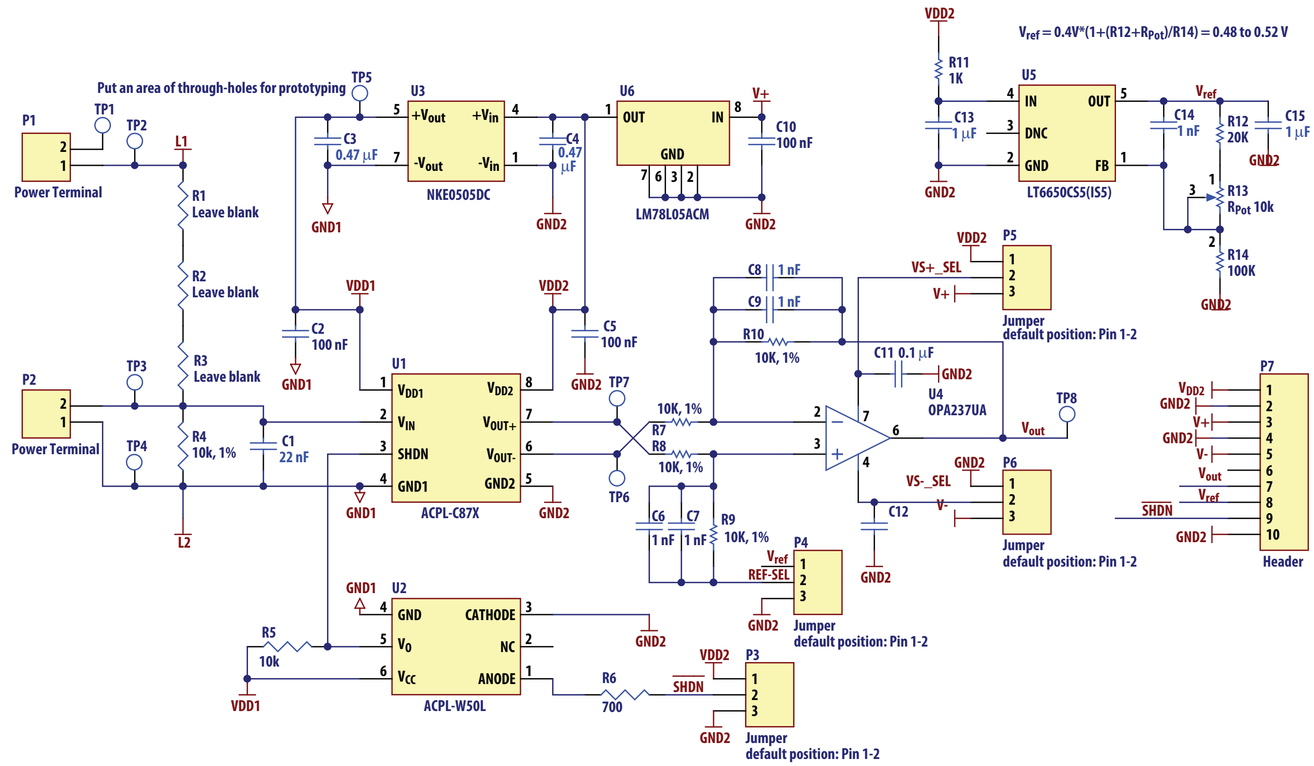

Figure 3. The ACPL-C87x evaluation board schematic

Given that the voltage sensor ACPL-C87x's nominal input voltage for V_{IN} is 2 V, a user needs to choose resistors R1, R2 and R3 according to Equation 1.

$$R1 + R2 + R3 = \frac{V_{L1} - V_{IN}}{V_{IN}} \times R4 \qquad \text{- Equation 1}$$

For example, if V_{L1} = 600 V, then the combined value of R1, R2 and R3 = 2990 kΩ.

Choosing resistors is flexible. One method is to combine several resistors to match the target value; e.g., 2 MΩ, 430 kΩ and 560 kΩ resistors make up 2990 kΩ exactly. In this way, V_{IN} of 2 V corresponds to V_{L1} of 600 V. However, in the cases that V_{L1} has a different value from 600 V, specific resistance values might be difficult to find. Another method is to round up the target value to a convenient value 3 MΩ to make choosing resistors easier; e.g., 1 MΩ is a common value and 3 pieces of it make 3 MΩ. In this way, the scaling relationship needs some fine tune. In the same example with V_{L1} = 600 V, R1+R2+R3 = 3 MΩ, and R4 = 10 kΩ, V_{IN} is solved to be 1.993 V.

After deciding resistance for R1 through R3, surface mount type devices can be mounted on the footprints provided. In case only through-hole type resistors are available, the prototyping area can be used instead.

The down-scaled input voltage is filtered by the anti-aliasing filter formed by R4 and C1 with corner frequency of 723 Hz [1] and then sensed by the ACPL-C87x. A differential output voltage that is proportional to the input voltage is created on the other side of the optical isolation barrier.

Note: 1. The total value of R1 through R3 in series is usually much larger than R4, therefore neglected in calculation.

Following the isolation amplifier, an OPA237 configured as a difference amplifier converts the differential signal to a single-ended output. This stage can be configured to further amplify the signal, if required, and form a low-pass filter to limit the bandwidth. In this circuit, the difference amplifier is designed for a gain of 1 with a low-pass filter corner frequency of 8 kHz. Resistors R9 and R10 can be selected for a different gain. The bandwidth can be reduced by increasing capacitance for C6 and C8.

With the ACPL-C87x gain of 1 and P4 jumper position on P1-2, the overall transfer function is:

$$V_{OUT} = V_{IN} + V_{REF}$$ - Equation 2

or

$$V_{OUT} = \frac{V_{L1}}{(R1+R2+R3)/R4+1} + V_{REF}$$ - Equation 3

As long as the P4 jumper position remains on P1-2, then Equation 2 and 3 hold true. If the P4 jumper is changed to P2-3, then the V_{REF} in Equation 2 and 3 will be set to 0 V. In this case, the onboard offset calibration function discussed in the subsequent section cannot be used.

Output voltage V_{OUT} representing the line voltage on the high voltage side is connected to the controller through P7 pin 7.

Power Supplies

The ACPL-C87x evaluation board operates from a single 5 V or dual supply up to ±15 V. To operate the board from a single 5 V supply:

1. Leave header jumpers P3 through P6 at their default positions as indicated in the schematic (Figure 3).
2. Connect the 5 V supply source to nodes V_{DD2} and GND2 through P7 pin 1 and 2. In many cases, the 5 V supply is the same power supply for the signal processing and control device.

To operate the board from dual supply such as ±10 V:

1. Connect +10 V, COM and -10 V to nodes V+, GND2 and V- through P7 pin 3, 4 and 5, respectively.
2. Change P5 and P6 jumpers pin 2-3 position, respectively.

In the dual supply method, the V_{DD2} [1] node receives 5 V supply through a voltage regulator LM78L05 (U6) from V+ node; therefore, a recommendation for V+ node is +7 V to +15 V.

Besides supplying to the ACPL-C87x output side, it is also connected to an isolated DC-DC converter (U3) to produce a floating 5 V supply. This floating 5 V supply, denoted as V_{DD1}, is used to operate the ACPL-C87x input side and the ACPL-W50L optocoupler. The isolated DC-DC converter is included in the evaluation board for evaluation convenience. To make this isolated voltage sensing solution cost-effective in mass production, the 5 V supply would usually be supplied by a floating power supply, which in many applications could be the same supply that is used to drive the high-side power transistor. A simple three-terminal voltage regulator will provide a stable voltage. Another method is to add an additional winding to an existing transformer to produce a 5 V supply.

Note:
1. The ACPL-C87X data sheet specifies VDD2 of 3 V to 5.5 V.

Onboard Offset Calibration

A voltage reference device, the U5 LT6650 in Figure 3, is included in the circuit to provide a shifted “virtual ground” for VOUT, thereby enables onboard offset calibration. To use this function, follow these simple steps:

1. Provide power supply to the board. Ensure the P4 jumper position is at Pin 1-2.
2. Set line voltage to the evaluation board to 0 V, or leave it unconnected.
3. Adjust the trimmer resistor R13 to set V_{OUT} reading at 0.500 V.

With these steps, V_{OUT} of 0.500 V corresponds to a 0 V of V_{IN}, therefore offset voltage due to the voltage sensor ACPL-C87x and the post-amp OPA237 is calibrated out. The controlled offset of 0.500 V then needs to be registered in the following stage signal processor and subtracted from measurement readings to obtain actual voltage sensor input.

Voltage Sensor Shutdown

The voltage sensor ACPL-C87x features a shutdown mode, which can be activated with a high level logic input on the shutdown pin (pin 3). In this mode, the IDD1 supply current is reduced to only 15 µA, making it suitable for battery-powered devices and other power-sensitive applications. In the evaluation circuit, the optocoupler U2 ACPL-W50L sends the shutdown logic from the low voltage controller side across the isolation barrier to the voltage sensor shutdown pin SHDN. Controller shutdown signal through P7 pin 9 needs to be a Low logic as the ACPL-W50L produces inversed signal from input to output. To manually turn the ACPL-C87x to shutdown mode, jumper P3 can be used: put jumper on pin 1-2 for normal operation; change to pin 2-3 to shut down.

In shutdown mode, the ACPL-C87x outputs topple to saturated levels to differentiate from normal operation mode. Table 1 lists the voltage sensor outputs and the post-amp output when the voltage sensor is on standby.

Table 1.

ACPL-C87x				OPA237	
V_{IN}	V_{OUT+}	V_{OUT-}	$V_{OUT+} - V_{OUT-}$	V_{OUT} (test conditions)	
0 – 3 V	0.005 V	2.75 V	-2.74 V	0.23 V (single 5 V supply)	-2.74 V (dual ±10 V supply, REF-SEL connected to V_{REF}); -2.24 V (dual ±10 V supply, REF-SEL connected to GND2)

Note:
When the board is operated from a dual supply, the V_{OUT} can reach -2.74 V when the voltage sensor is shut down. If this voltage is directly connected to an ADC input, then some means of protection are required to protect the ADC from damage.

Use the Board with Caution

To use the board for bench measurement that involves only a low voltage of several volts from an isolated voltage source, a user can connect input to P2 directly, without the need of the resistive divider. Adjust the input voltage to an appropriate level to carry out measurements.

To connect the board to a high voltage source such as a DC-link bus or a photovoltaic panel output, the user can connect the high voltage nodes to P1 pin 1 and P2 pin 1, using the onboard voltage divider with appropriate resistors mounted to R1 through R3 footprints. If through-hole resistors are used to implement the voltage divider, the prototyping area can be used -- connect high voltage across P1 pin 2 and P2 pin 1. With high voltage presence on the board, **caution of electric shock** is required when handling the board as the high voltage side is not shielded.

Figure 4 shows an oscilloscope screen shot of a measurement with V_{IN} = 0 V to 2 V linear input, and V_{OUT} = 0.5 V to 2.5 V linear output. The difference of 0.5 V is the V_{REF} set during calibration.

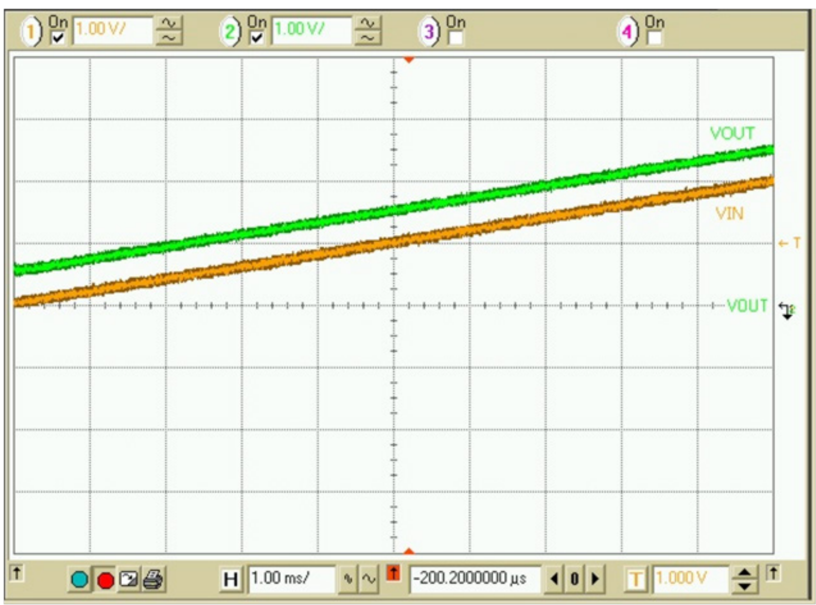

Figure 4. Scope screen shot of a measurement with 0-2 V linear input

AV02-4293EN - September 11, 2013