Isolated 24 V Power Supply Window Monitor Options

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The 24 V field voltage is commonly used on the factory floor. It powers field transmitters, sensors, actuators, and more. According to IEC61131, the 24 V has a tolerance of -15% to +20%, which translates to a voltage range of 20.4 V to 28.8 V. In critical applications, the PLC side may need to know whether the voltage is in the valid range for correct operation. There may be no inbound isolation path to get the information to the PLC side, though. Just think about an output-oriented application like an analog output module. The processor feeds the data to the DAC where all serial interface signals are outbound-directed (for example, SCLK, CS, and DOUT of an SPI). The power valid signal you want to transfer may also sneak in here by spending an additional channel in an anyway-used digital isolator (see Figure 1). In applications where this is not possible or size/power consumption is not a big constraint, Option 2 or Option 3 may be of interest.

Option 1: Digital Isolator with Back Channel and Window Comparator

For the DAC example described above, a digital isolator with three channels (ISO7730) works, but the four channel derivative (ISO7741) can be used to transfer the power supply information. The TLV6700, a window comparator with internal reference, and open-drain outputs monitors the power supply voltage. It outputs high if the voltage is in the expected range or outputs low otherwise. The resistor ladder for the window comparator is calculated using the procedure presented in Window Comparator with Integrated Reference Circuit Application Note (SNVA832). For the calculation, the lower threshold (V_L) is set to 20.4 V and the higher threshold (V_H) is set to 28.8 V. See Figure 1 for the schematics.

The power supply for the TLV6700 comes "for free" as a 3.3-V to 5-V voltage rail. It is required for the isolator anyway (pin VCC2). The supply rail VCC_ISO is generated from VIN, meaning if the power is lost at the PLC side, the power of the isolator on the isolated side (pin VCC2) also goes down. As a consequence, the ISO7741F sets the output of channel D (pin OUTD) low. This presents a reliable fault to the processor down to zero voltage (power loss). The TLV6700 starts operating at 1.8 V while the ISO77xx family starts at 2.25 V. This always ensures a valid level at the isolator input when powered up.

The TLV6700 has 1% detection accuracy on the overvoltage (OV) threshold, and 1.5% for the undervoltage (UV) detection. The resistor ladder-produced voltage has 1.9% accuracy when 1% resistors are used. Using the sum of squares gives 2.3% overall accuracy for OV detection, and 2.4% for UV detection.

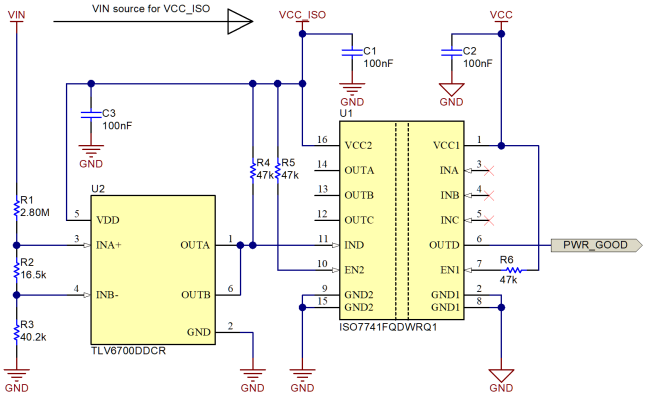

Figure 1. Schematics Option 1

Option 2: Dedicated Isolator with Shunt Reference

The second option consists of two components: The ISO1211, an isolated 24-V to 60-V digital input receiver, and the shunt reference TL431LIAQ. If the field voltage is in valid range, the ISO1211 outputs high, otherwise it is low. The ISO1211 takes care of the isolation and the lower threshold detection. See Figure 2 for the schematics of this circuit.

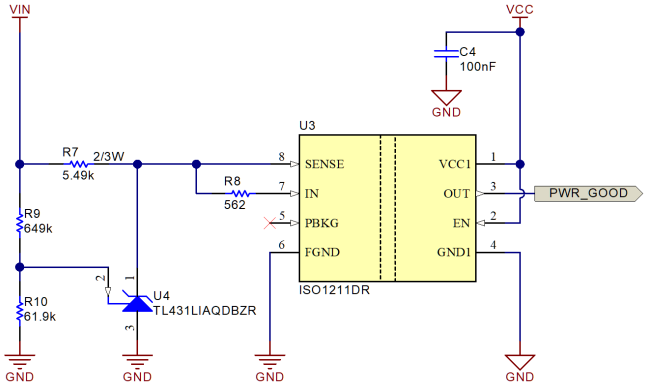

Figure 2. Schematics option 2

The lower, positive-edge, threshold is set by R7 and R8. R8 sets the required input current, I_L, which is set to the lowest possible current of 2.25 mA. R7 and R8 define the lower voltage threshold of the window comparator.

$$V_{IH(TYP)} < 8.25\ V + R_7 \times \frac{2.25\ mA * 562\ \Omega}{R_8} \quad (1)$$

With a field supply threshold of 20.4 V, the threshold resistor R7 is 5.4 kΩ (5.49 kΩ of E96 series). The upper, negative-edge, threshold is triggered by the TL431LIAQ. The resistor divider R9/R10 sets the threshold. The minimum current through the divider is set to 40 µA (100x the reference input current of TL431LIAQ). The resistance of the divider for the upper threshold voltage of 28.8 V should therefore not exceed 720 kΩ.

The reference voltage of the TL431LIAQ is 2.495 V nominal. The resistor divider splits up to 28.8 V/ 2.495 V = 11.54:1. R10 must not exceed 720 kΩ / 11.54 = 62.39 kΩ (61.9 kΩ). R9 results in 62.39 kΩ × (11.54 - 1) = 658 kΩ (649 kΩ). With real resistor values, the upper threshold excluding errors is calculated by:

$$V_{IN} = V_{REF\_TL431} \times \frac{R10+R9}{R10} = 2.495V \times \frac{61.9k\Omega+649k\Omega}{61.9k\Omega} = 28.65V \quad (2)$$

As soon as this threshold is reached, the TL431LIAQ conducts and provides a low impedance path to ground. As a result, the input voltage at the ISO1211 goes below the lower threshold, forcing a low at the ISO1211 output.

The circuit works with an input voltage up to 75 V. The current thought the TL431LIAQ for a SELV/PELV power supply with 60 V input voltage (max) is about 12 mA. According to the simulation, the voltage drop across R7 at 60 V input voltage is 59.08 V. This results in a maximum power dissipation of P_{MAX_R7} = 0.636 W in this overvoltage condition. A reverse polarity input connection is also tolerated down to a input voltage of -55 V. The ISO1212 can be used for a dual voltage monitor.

The TL4311LIAQ is quite accurate for OV detection – it has 0.6% accuracy. If a 1.7% voltage accuracy out of the 1% resistor ladder is considered, the OV detection accuracy is about 1.8%. The case for the UV is worse, as the ISO1211 has about 7% inaccuracy for threshold detection. This leaves UV detection at about 7% accuracy.

Option 3: Dedicated Isolator with Window Comparator

The third option consists of window comparator TLV6710. The TLV6710 is similar to the TLV6700, but with a supply voltage up to +36 V and a slightly different threshold. The resistor ladder is adapted accordingly. The isolation is performed by the ISO1211. The window comparator ensures that the open-drain output is low in case the supply is out of the valid voltage range (OV/UV condition). The ISO1211 gets the required 2.25 mA as long as the window comparator output is high to generate output high on the processor side. The TLV6700 can withstand voltage up to 40 V, and has a level detection accuracy of ±1.4%. The 1% resistor ladder has an accuracy of ±1.9%. Using sum of squares, the expected accuracy of this OV/UV detector is better than ±2.4%.

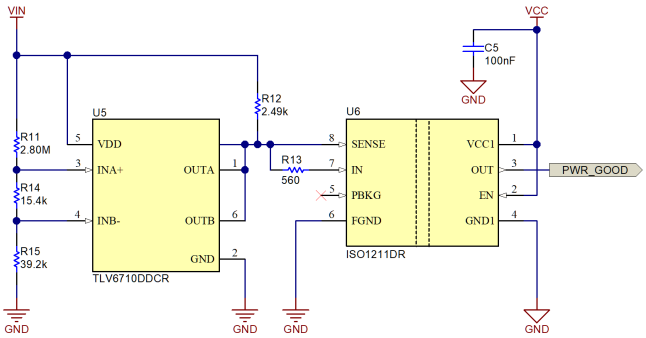

Figure 3. Schematics Option 3

Table 1. Comparison of the Three Options

COMPARISON PARAMETER	OPTION 1	OPTION 2	OPTION 3
Devices	ISO7741F, TLV6700	ISO1211, TL431LIAQ	ISO1211, TLV6710
Input Voltage	0...>100 V	0..75 V	0..40 V
Reverse polarity protected	No	Yes	No
Accuracy	~±2.4%	~±1.8% OV, ±7% UV	~±2.4%
Power consumption (nominal)	~7 mW (ISO7741F: one channel)	~55 mW	~55 mW
Isolation	Reinforced/basic	Basic	Basic
Temperature range	-40ºC to +125ºC	-40ºC to +125ºC	-40ºC to +125ºC
Size	Small	Medium	Medium
Cost	$$	$	$$$
Application	Needs to fit in application concept	Independent of other application circuit	Independent of other application circuit

References

- TLV6700 Product Page
- TLV6710 Product Page
- ISO7741 Product Page
- ISO1211 Product Page
- TL431LI-Q1 Product Page

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