Analog Engineer's Circuit

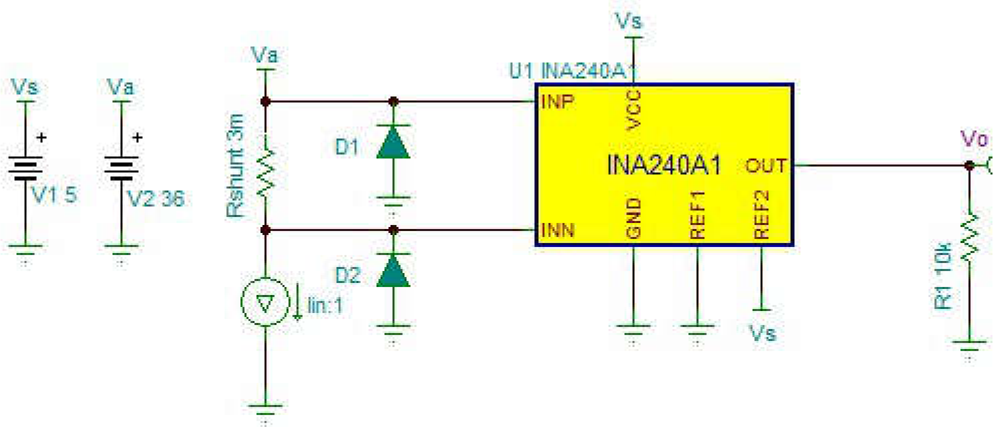
High-Side, Bidirectional Current-Sensing Circuit with Transient Protection

Design Goals

Input		Output		Supply			Standoff and Clamp Voltages		EFT Level
I_{inMin}	I_{inMax}	V_{oMin}	V_{oMax}	Vs	GND	V_{ref}	Vwm	Vc	Vpp
–40 A	40 A	100 mV	4.9 V	5 V	0 V	2.5 V	36 V	80 V	2 kV 8/20 µs

Design Description

This high-side, bidirectional current sensing solution can accurately measure current in the range of –40 A to 40 A for a 36 V voltage bus. The linear voltage output is 100 mV to 4.90 V. This solution is also designed to survive IEC61000-4-4 level 4 EFT stress (Voc = 2 kV; Isc = 40 A; 8/20 µs).



Design Notes

1. This solution is targeted toward high-side current sensing.
2. The sense resistor value is determined by minimum and maximum load currents, power dissipation and Current Shunt Amplifier (CSA) gain.
3. Bidirectional current sensing requires an output reference voltage (Vref). Device gain is achieved through internal precision matched resistor network.
4. The expected maximum and minimum output voltage must be within the device linear range.
5. The TVS diode must be selected based on bus voltage, the CSA common-mode voltage specification, and EFT pulse characteristics.

Design Steps

1. Determine the maximum output swing:

$$\mathrm{VswN} = Vref - VoMin = 2.5\mathrm{V} - 0.1\mathrm{V} = 2.4\mathrm{V}$$

$$\mathrm{VswP} = VoMax - Vref = 4.9\mathrm{V} - 2.5\mathrm{V} = 2.4\mathrm{V}$$

2. Determine the maximum value of the sense resistor based on maximum load current, swing and device gain. In this example, a gain of 20 was chosen to illustrate the calculation, alternative gain versions may be selected as well:

$$\mathrm{Rshunt} \le \frac{\mathrm{Vswp}}{\mathrm{Iin\_max} \times \mathrm{Gain}} = \frac{2.4\mathrm{V}}{40\mathrm{A} \times 20} = 3\mathrm{m}\ \Omega$$

3. Calculate the peak power rating of the sense resistor:

$$\mathrm{Pshunt} = \mathrm{Iin\_max}^2 \times \mathrm{Rshunt} = 40\mathrm{A}^2 \times 3\mathrm{m}\ \Omega\ = 5\mathrm{W}$$

4. Determine TVS standoff voltage and clamp voltage:

$$\mathrm{Vwm} = 36\mathrm{V} \quad \text{and} \quad \mathrm{Vc} \le 80\mathrm{V}$$

5. Select a TVS diode.

   For example, SMBJ36A from Littelfuse™ satisfies the previous requirement, with peak pulse power of 600 W (10/1000 μs) and current of 10.4 A.
6. Make sure the TVS diode satisfies the design requirement based on the TVS operating curve.

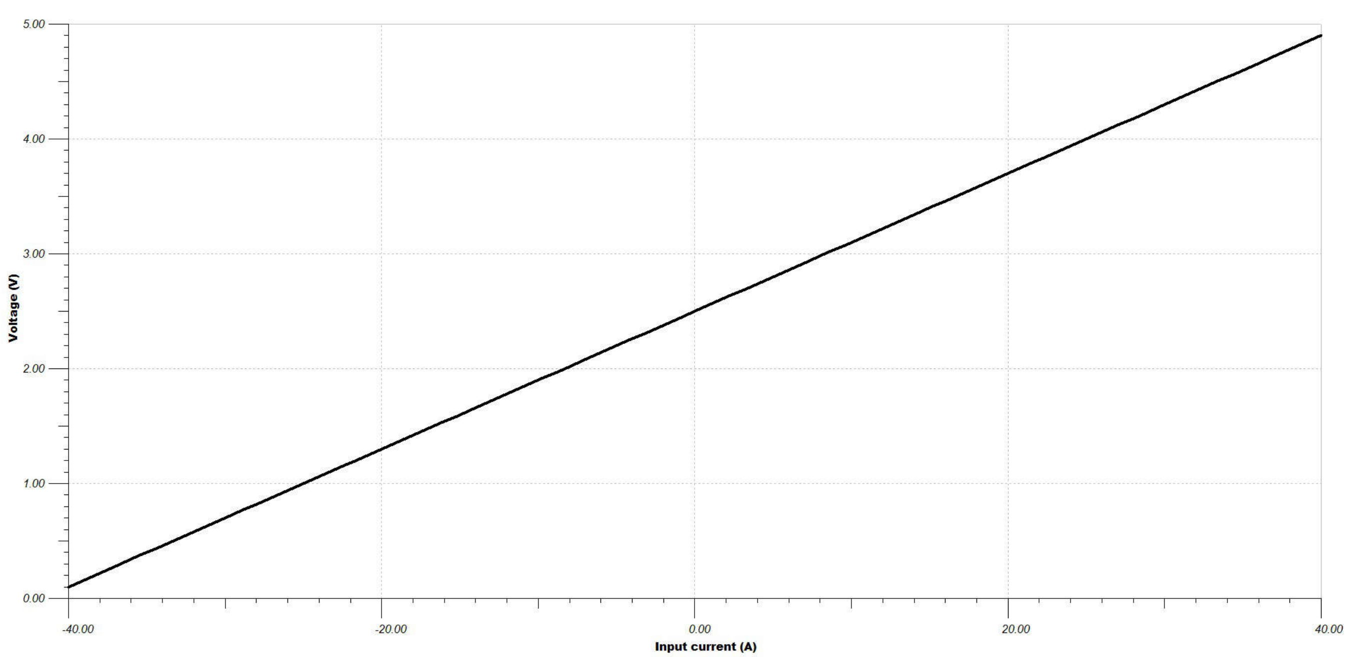
   Peak pulse power at given excitation (8/20 μs) is estimated to be around 3.5 kW, which translates to peak pulse current:

$$\mathrm{Ipp} = \frac{3.5\mathrm{kW}}{600\mathrm{W}} \times 10.4\mathrm{A} = 60\mathrm{A}$$

This is above the maximum excitation (short circuit) current of 40 A. The select TVS effectively protects the circuit against the specified EFT strike.

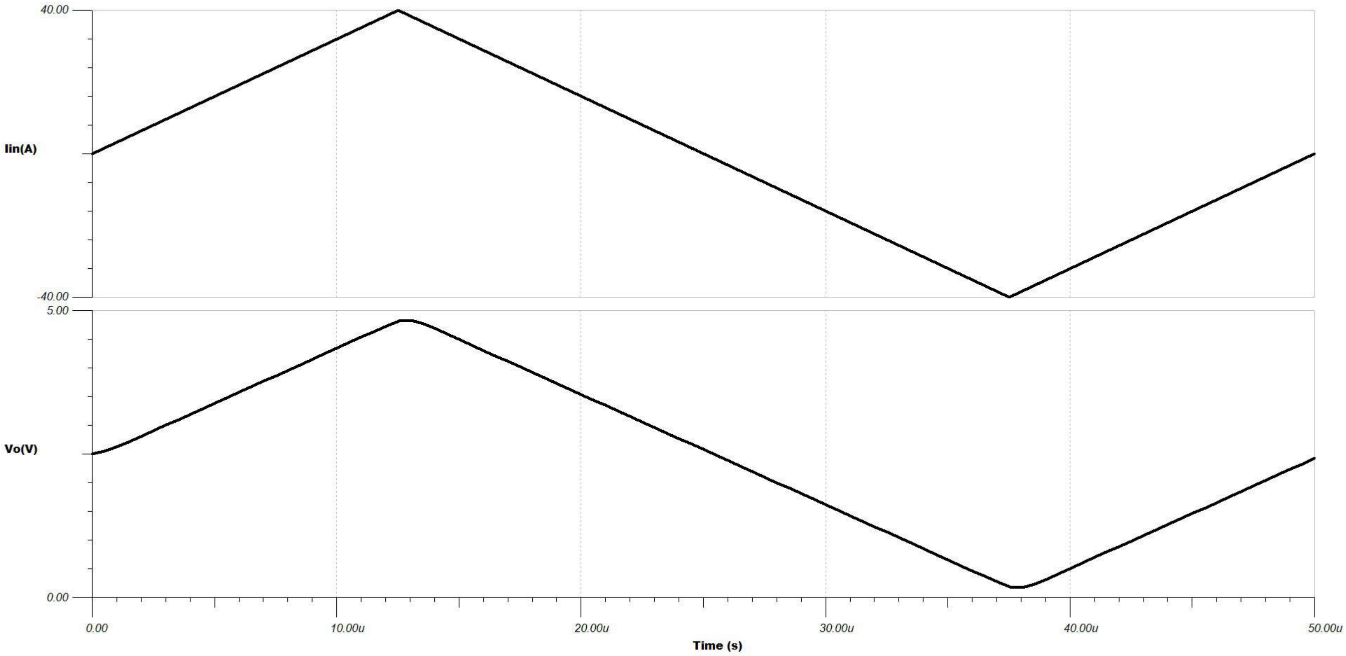
Design Simulations

DC Transfer Characteristics

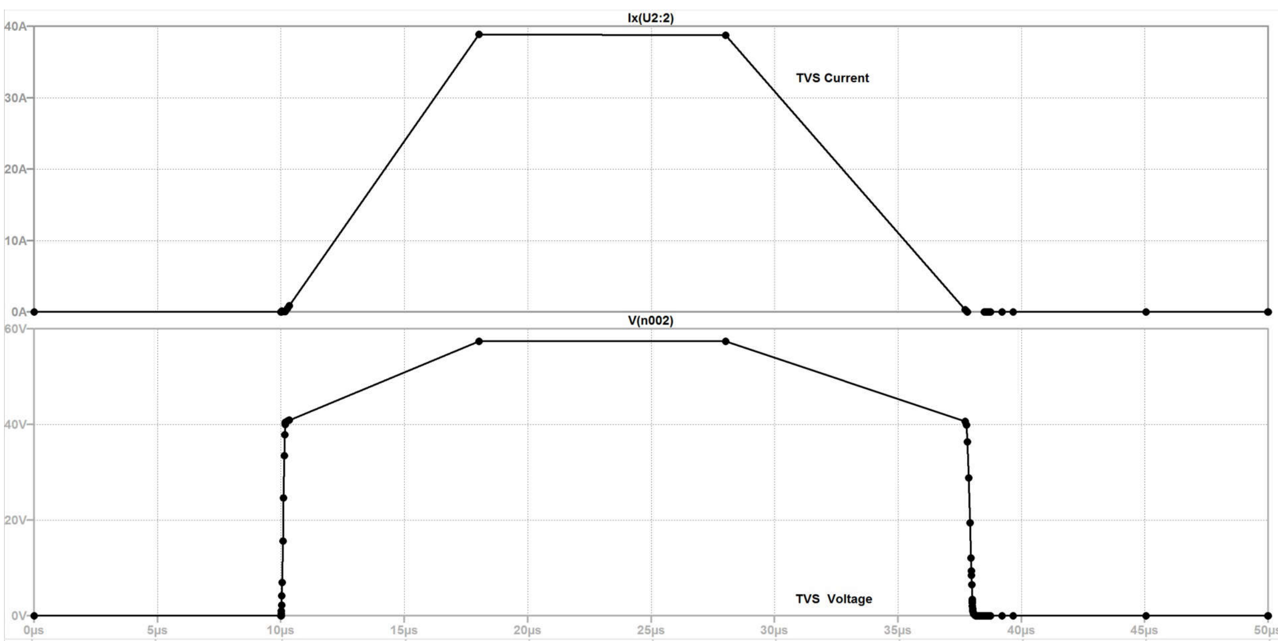


Transient Simulation Results

The output is a scaled version of the input.



TVS Diode Transient Response Under EFT Excitation



Design References

See *Analog Engineer's Circuit Cookbooks* for TI's comprehensive circuit library.

For more information on transient protection of the current sense amplifiers, see *TIDA-00302* and the *Current Sense Amplifier Training Videos*.

Design Featured Current Sense Amplifier

INA240A1	
V_s	2.7 V to 5.5 V
V_{CM}	–4 V to 80 V
V_{os}	Rail-to-rail
V_{os}	5 µV
I_B	80 µA
BW	400 kHz
Vos Drift	50 nV/°C
INA240A1	

Design Alternate

INA282	
V_s	2.7 V to 18 V
V_{CM}	–14 V to 80 V
V_{os}	20 µV
I_B	25 µA
BW	10 kHz
Vos Drift	0.3 µV/°C
INA282	

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from May 15, 2018 to February 19, 2019	Page
• Changed VinMin and VinMax in the *Design Goals* table to IinMin and IinMax, respectively.	1

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