

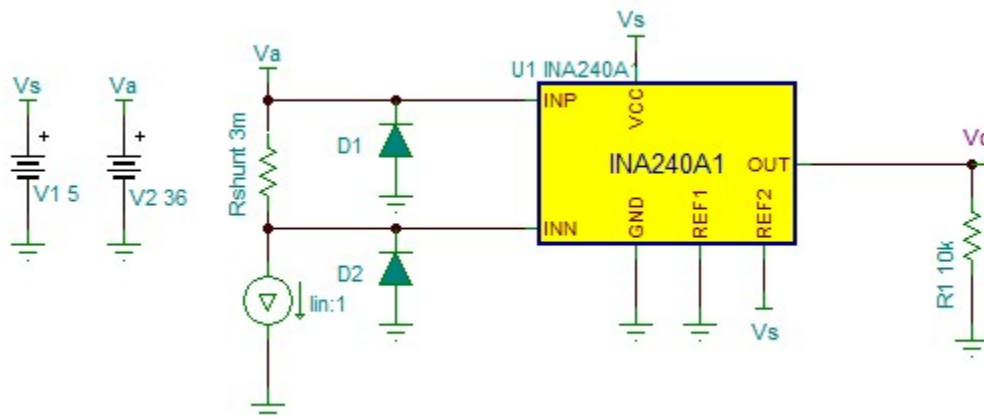
High-side, bidirectional current-sensing circuit with transient protection

Design Goals

Input		Output		Supply			Standoff and Clamp Voltages		EFT Level
I_{inMin}	I_{inMax}	V_{oMin}	V_{oMax}	V_s	GND	V_{ref}	V_{wm}	V_c	V_{pp}
-40A	40A	100mV	4.9V	5V	0V	2.5V	36V	80V	2kV 8/20 μ s

Design Description

This high-side, bidirectional current sensing solution can accurately measure current in the range of -40A to 40A for a 36-V voltage bus. The linear voltage output is 100mV to 4.90V. This solution is also designed to survive IEC61000-4-4 level 4 EFT stress ($V_{oc} = 2kV$; $I_{sc} = 40A$; 8/20 μ s).



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 (V_{ref}). 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:

$$V_{swN} = V_{ref} - V_{oMin} = 2.5V - 0.1V = 2.4V$$

$$V_{swP} = V_{oMax} - V_{ref} = 4.9V - 2.5V = 2.4V$$

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:

$$R_{shunt} \leq \frac{V_{swp}}{I_{in_max} \times Gain} = \frac{2.4V}{40A \times 20} = 3m\Omega$$

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

$$P_{shunt} = I_{in_max}^2 \times R_{shunt} = 40A^2 \times 3m\Omega = 5W$$

4. Determine TVS standoff voltage and clamp voltage:

$$V_{wm} = 36V \quad \text{and} \quad V_c \leq 80V$$

5. Select a TVS diode.

For example, SMBJ36A from Littelfuse™ satisfies the previous requirement, with peak pulse power of 600W (10/1000μs) and current of 10.4A.

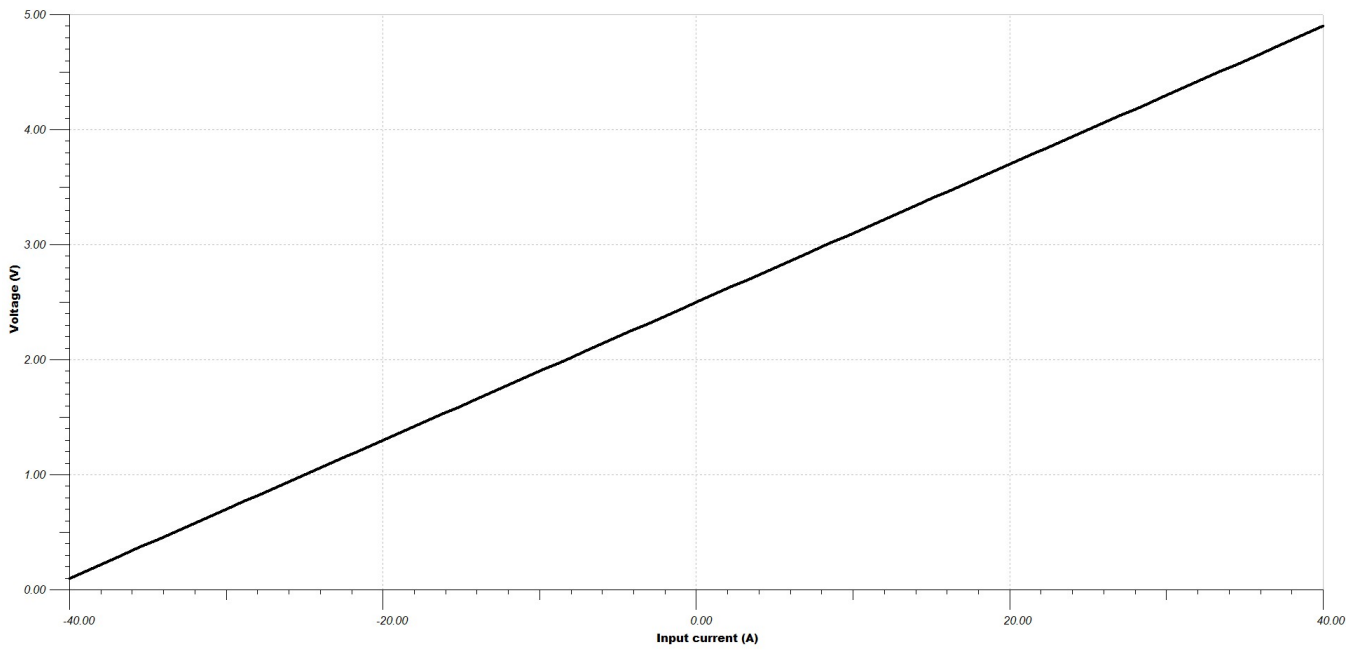
6. Make sure the TVS diode satisfies the design requirement based on the TVS operating curve.

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

$$I_{pp} = \frac{3.5kW}{600W} \times 10.4A = 60A$$

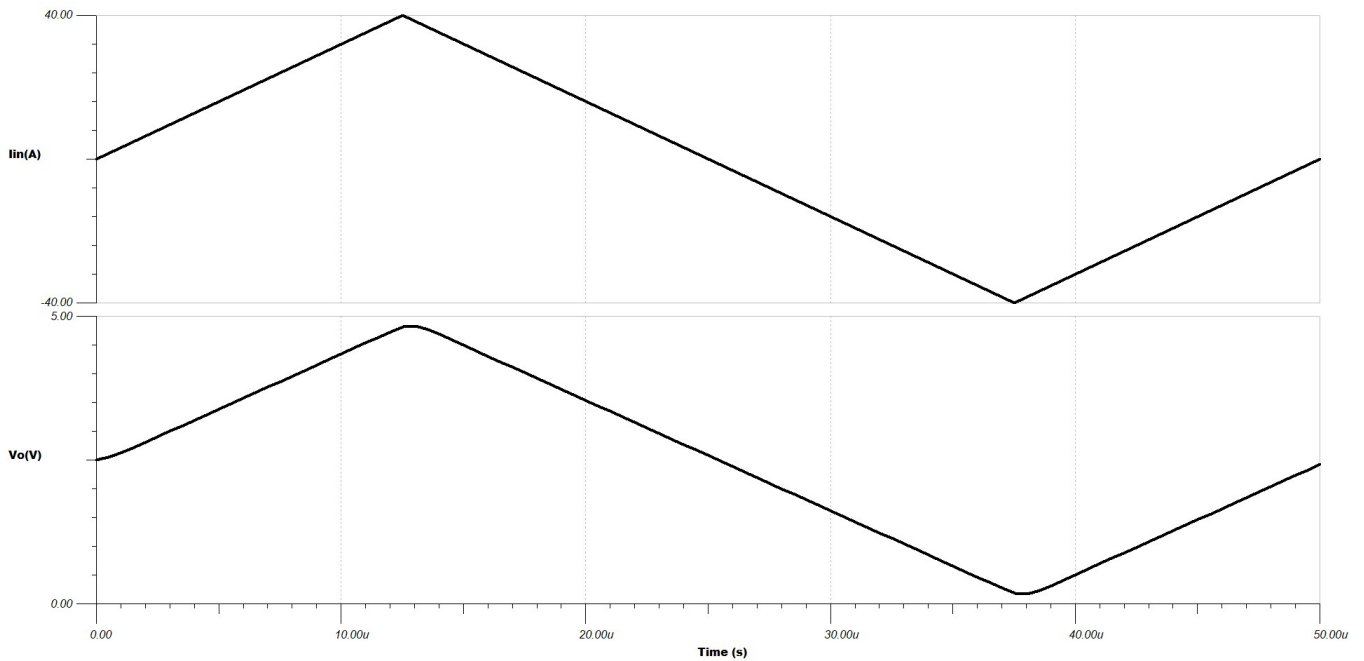
This is above the maximum excitation (short circuit) current of 40A. The select TVS effectively protects the circuit against the specified EFT strike.

Design Simulations
DC Transfer Characteristics

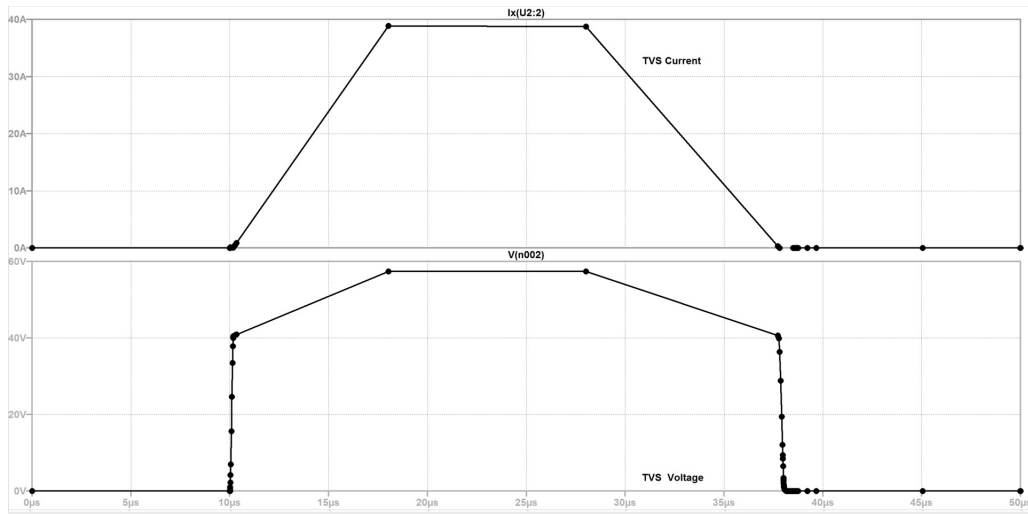


Transient Simulation Results

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	2.7V to 5.5V
V_{CM}	-4V to 80V
V_{os}	Rail-to-rail
V_{os}	5 μ V
I_B	80 μ A
BW	400kHz
Vos Drift	50nV/ $^{\circ}$ C
http://www.ti.com/product/INA240	

Design Alternate

INA282	
V_s	2.7V to 18V
V_{CM}	-14V to 80V
V_{os}	20 μ V
I_B	25 μ A
BW	10kHz
Vos Drift	0.3 μ V/ $^{\circ}$ C
http://www.ti.com/product/INA193	

Revision History

Revision	Date	Change
A	February 2019	Changed VinMin and VinMax in the <i>Design Goals</i> table to linMin and linMax, respectively.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2019, Texas Instruments Incorporated