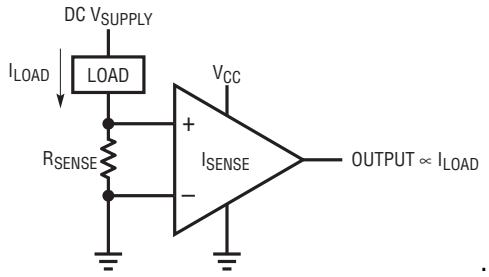
Current Sense Basics

This chapter introduces the basic techniques used for sensing current. It serves also as a definition of common terms. Each technique has advantages and disadvantages and these are described. The types of amplifiers used to implement the circuits are provided.

To see other chapters in this Application Note, return to the Introduction.

LOW SIDE CURRENT SENSING

Current sensed in the ground return path of the power connection to the monitored load. Current generally flows in just one direction (uni-directional). Any switching is performed on the load-side of monitor.



Low Side Advantages

- Low input common mode voltage
- Ground referenced output voltage
- Easy single supply design

Low Side Disadvantages

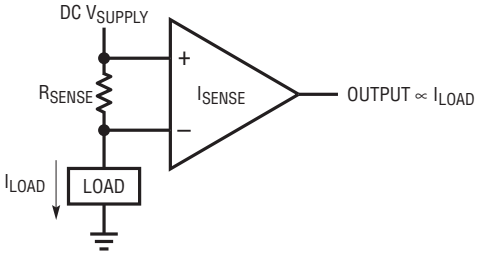
- Load lifted from direct ground connection
- Load activated by accidental short at ground end load switch
- High load current caused by short is not detected

Amplifier Types for Low Side Implementation

- Precision zero-drift op amps: LTC2050, LTC2054
- Instrumentation amplifiers: LTC2053, LT1990, LTC6943
- Rail-to-Rail Input op amps: LT1677

HIGH SIDE CURRENT SENSING

Current sensed in the supply path of the power connection to the monitored load. Current generally flows in just one direction (uni-directional). Any switching is performed on the load-side of monitor.



High Side Advantages

- Load is grounded
- Load not activated by accidental short at power connection
- High load current caused by short is detected

High Side Disadvantages

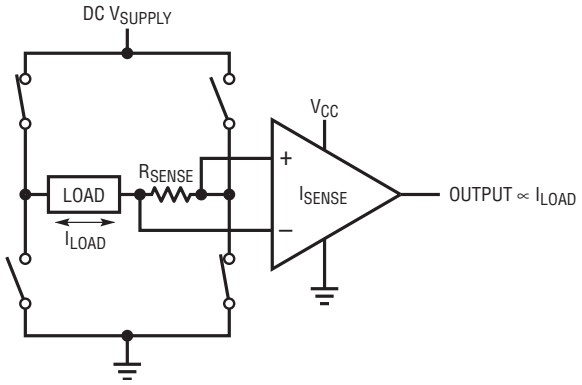
- High input common mode voltages (often very high)
- Output needs to be level shifted down to system operating voltage levels

Amplifier Types for High Side Implementation

- Dedicated current sensing amplifiers: LT6100, LTC6101, LT1787
- Over-the-Top™ op amps: LT1637
- Flying capacitor amplifier: LTC6943

FULL-RANGE (HIGH AND LOW SIDE) CURRENT SENSING

Bi-directional current sensed in a bridge driven load, or unidirectional high side connection with a supply side switch.



Full-Range Advantages

- Only one current sense resistor needed for bidirectional sensing
- Convenient sensing of load current on/off profiles for inductive loads

Full-Range Disadvantages

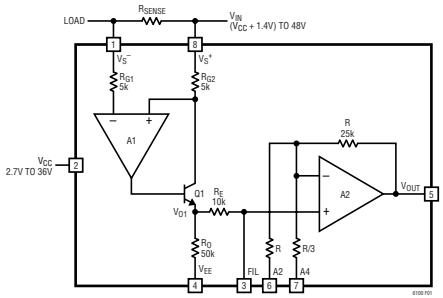
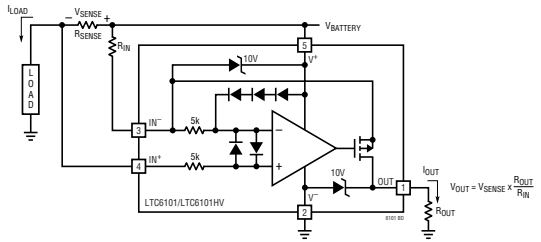
- Wide input common mode voltage swings
- Common mode rejection may limit high frequency accuracy in PWM applications

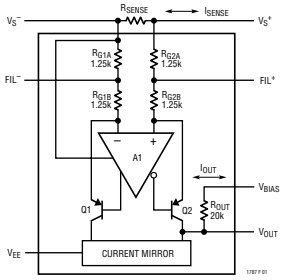
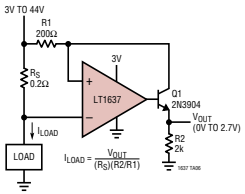
Amplifier Types for Bi-directional Implementation

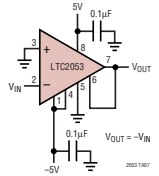
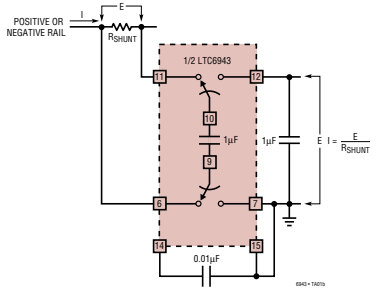
- Difference amplifiers-LT1990, LT1991, LT1995, LT1996
- Instrumentation amplifiers: LTC2053
- Flying capacitor amplifier: LTC6943

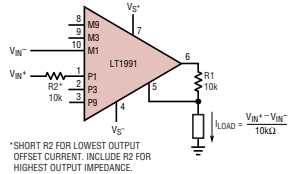
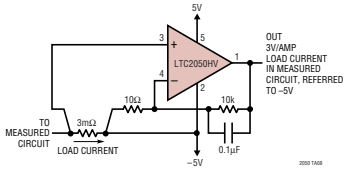
SUMMARY OF CURRENT SENSE SOLUTIONS

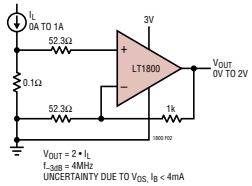
The next few pages contain a table that summarizes current sense solutions and applicable devices. Look first in the “Type/Circuit” column and the “Gain” column for a general description of the application. Then scan across the other columns for applicable devices and their specifications.

			ACCURACY		SPEED				
TYPE/CIRCUIT	**GAIN (V/V)**	**DEVICES AND PACKAGES**	**OFFSET VOLTAGE (V_{OS})**	**INPUT CURRENT (I_{BIAS})**	**BANDWIDTH**	**SLEW RATE**	**V_{SUPPLY} RANGE (V_S)**	**V_{IN} RANGE (VCM)**	**DIFFERENTIAL V_{IN} RANGE (SURVIVAL)**
■ High Side ■ One Direction ■ Voltage Out 	10 to 50	LT6100 MSOP-8 DFN	300µV	5µA	100kHz	0.05V/µs	2.7V to 36V	(V_S + 1.4V) to 48V	±48V
■ High Side ■ One Direction ■ Current Out 	Resistor Ratio	LTC6101 LTC6101HV SOT23-5 MSOP-8	350µV 350µV	250nA 250nA	200kHz 200kHz	2.5V/µs 2.5V/µs	4V to 70V 4V to 105V	(V_S – 1.5V) to 70V (V_S – 1.5V) to 105V	±70V ±105V

			ACCURACY		SPEED				
TYPE/CIRCUIT	**GAIN (V/V)**	**DEVICES AND PACKAGES**	**OFFSET VOLTAGE (V_{OS})**	**INPUT CURRENT (I_{BIAS})**	**BANDWIDTH**	**SLEW RATE**	**V_{SUPPLY} RANGE (V_S)**	**V_{IN} RANGE (VCM)**	**DIFFERENTIAL V_{IN} RANGE (SURVIVAL)**
■ High Side ■ Bi-directional ■ Current or Voltage (R_{OUT} = 20k) 	Fixed 8 or Scaleable	LT1787 LT1787HV SO-8 MSOP-8	75µV 75µV	20µA 20µA	300kHz 300kHz	0.1V/µs 0.1V/µs	2.5V to 36V 2.5V to 60V	2.5V to 36V 2.5V to 60V	±10V ±10V
■ High Side ■ One Direction ■ Voltage Out ■ Over the Top Amplifiers 	Resistor Ratio	LT1494 LT1636 LT1637 LT1672 LT1782 LT1783 LT1784 DIP-8 MS-8 SO-8 DFN SOT23-5 SOT23–6	150µV 50µV 100µV 150µV 400µV 400µV 1500µV	250pA 5nA 20nA 250pA 8nA 45nA 250nA	3kHz 200kHz 1MHz 12kHz 200kHz 1.25MHz 2.5MHz	0.001V/µs 0.07V/µs 0.35V/µs 0.005V/µs 0.07V/µs 0.42V/µs 2.4V/µs	2.1V to 36V 2.6V to 44V 1.8V to 44V 2.1V to 36V 2.2V to 18V 2.2V to 18V 2V to 18V	0 to V_S + (36V – V_S) 0 to V_S + (44V – V_S) 0 to V_S + (44V – V_S) 0 to V_S + (36V – V_S) 0 to V_S + (18V – V_S) 0 to V_S + (18V – V_S) 0 to V_S + (18V – V_S)	36V 44V 44V 36V 36V 36V 36V

			ACCURACY		SPEED				
TYPE/CIRCUIT	**GAIN (V/V)**	**DEVICES AND PACKAGES**	**OFFSET VOLTAGE (V_{OS})**	**INPUT CURRENT (I_{BIAS})**	**BANDWIDTH**	**SLEW RATE**	**V_{SUPPLY} RANGE (V_S)**	**V_{IN} RANGE (VCM)**	**DIFFERENTIAL V_{IN} RANGE (SURVIVAL)**
■ High Side ■ One Direction ■ Voltage Out ■ Instrumentation Amplifier 	Resistor Ratio	LTC2053 LTC6800 DFN MS-8	5µV 5µV	4nA 4nA	200kHz 200kHz	0.2V/µs 0.2V/µs	2.7V to 11V 2.7V to 5.5V	2.7V to 11V 2.7V to 5.5V	5.5V 5.5V
■ High Side or Low Side ■ One Direction ■ Voltage on a capacitor output ■ Flying Capacitor 	Unity	LTC6943 TSSOP – 16		6pA	90kHz		5V to 18V	5V to 18V	18V

			ACCURACY		SPEED				
TYPE/CIRCUIT	**GAIN (V/V)**	**DEVICES AND PACKAGES**	**OFFSET VOLTAGE (V_{OS})**	**INPUT CURRENT (I_{BIAS})**	**BANDWIDTH**	**SLEW RATE**	**V_{SUPPLY} RANGE (V_S)**	**V_{IN} RANGE (VCM)**	**DIFFERENTIAL V_{IN} RANGE (SURVIVAL)**
■ High Side or Low Side	1 and 10	LT1990	900µV	2.5nA	105kHz	0.55V/µs	2.4V to 36V	–250V to 250V	±250V
■ Bi-Directional	1 to 13	LT1991	15µV		110kHz	0.12V/µs	2.7V to 36V	–60V to 60V	±60V
■ Voltage Out	1 to 7	LT1995	1000µV	2.5nA	32MHz	1000V/µs	5V to 36V	0V to 36V	V_S + 0.3V
■ Difference Amplifiers	9 to 117	LT1996	15µV		38kHz	0.12V/µs	2.7V to 36V	–60V to 60V	±60V
	Pin Strap Configurable	SO-8 DFN MS–10							
■ Low Side	Resistor Ratio	LTC2050	0.5µV	75pA	3MHz	2V/µs	2.7V to 7V	0V to (V_S – 1.3V)	V_S + 0.3V
■ One Direction		LTC2054	0.5µV	0.6pA	500kHz	0.5V/µs	2.7V to 7V	0V to (V_S – 0.7V)	V_S + 0.3V
■ Voltage Out		LTC2054HV	0.5µV	0.6pA	500kHz	0.5V/µs	2.7V to 12V	0V to (V_S – 0.7V)	V_S + 0.3V
■ Zero-Drift Amplifiers		SO-8 SOT23-5 SOT23 – 6							
									

			ACCURACY		SPEED				
TYPE/CIRCUIT	**GAIN (V/V)**	**DEVICES AND PACKAGES**	**OFFSET VOLTAGE (V_{OS})**	**INPUT CURRENT (I_{BIAS})**	**BANDWIDTH**	**SLEW RATE**	**V_{SUPPLY} RANGE (V_S)**	**V_{IN} RANGE (VCM)**	**DIFFERENTIAL V_{IN} RANGE (SURVIVAL)**
■ Low Side ■ One Direction ■ Voltage Out ■ Rail to Rail I/O Amplifiers 	Resistor Ratio	LT1218 LT1677 LT1800 LT1806 LT6200 LT6220 SO-8 DIP-8 SOT23-5 SOT23 – 6	25µV 20µV 75µV 100µV 1400µV 70µV	30nA 2nA 25nA 1µA 10µA 15nA	300kHz 7.2MHz 80MHz 325MHz 110MHz 60MHz	0.1V/µs 2.5V/µs 25V/µs 125V/µs 50V/µs 20V/µs	2V to 36V 2.5V to 44V 2V to 12.6V 1.8V to 12.6V 2.2V to 12.6V 2.2V to 12.6V	0V to V_S 0V to V_S 0V to V_S 0V to V_S 0V to V_S 0V to V_S	V_S + 0.3V V_S + 0.3V V_S + 0.3V V_S + 0.3V V_S + 0.3V V_S + 0.3V