LTC6115
High Voltage High Side Current and Voltage Sense

DESCRIPTION

Demonstration circuit 2839A is a high voltage, high side current sense circuit featuring the LTC®6115. This circuit measures inputs up to 100V and 2A. The board can be connected to Linduino® as a shield and has an accompanying Linduino sketch. The gain of the current sense channel may be set with jumpers to 5V/A (100V/V) or 2.5V/A (50V/V), and the gain of the voltage sense channel may be selected with jumpers for unity gain or 2V/V.

The DC2839A includes a 4-terminal 50mΩ sense resistor with a footprint for larger, higher-power rated parts. A 1:1000 resistor divider can be selected with jumpers to provide simulated mV-scale input difference voltages if high currents are not available.

The voltage sense and current sense can be configured to measure the same input or separate inputs.

An external 5V to 100V power source is needed for input and current sense supply. The voltage sense supply can be either an external 2.7V to 5.5V power source or drawn from a Linduino (DC2026C) board when DC2839A is used as a Linduino shield. An optional electronic load capable of sinking up to 2A at 100V can also be used as input to the current sense. Turrets are provided for input and output, along with Linduino shield connectors to Linduino's onboard ADC inputs.

Design files for this circuit board are available.

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PERFORMANCE SUMMARY

Specifications are at T_A = 25°C, $V_{SENSE}^+ = V^+$, 5V ≤ V^+ ≤ 100V

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Current Sense						
	Supply Voltage Range (V^+)		5		100	V
$V_{SENSE(MAX)}$	Input Sense Voltage Full-Scale	Error < 1%, R_{IN} = 1kΩ	500			mV
I_{OUTI}	Maximum Output Current	R_{OUT} = 2kΩ, V_{SENSE} = 110mV, Gain = 20	1			mA
t_r	Input Step Response (to 2.5V on a 5V Output Step)	ΔV_{SENSE} = 100mV Transient, Gain = 50, V^+ = 5V		1.5		µs
I_V^+	Amplifier Supply Current	V^+ = 5V, I_{OUTI} = 0, R_{IN} = 1MΩ V^+ = 100V, I_{OUTI} = 0, R_{IN} = 1MΩ		240 400	450 640	µA µA
Voltage Sense, V_S = 5V						
V_S	Supply Voltage Range	Guaranteed by PSRR Test	2.7		5.5	V
	V_{IN} Voltage Range	Referred to GND	0		100	V
ΔG	Total Gain Error	V_{IN} = 100V, No Load		0.03	±0.15	%
I_S	Amplifier Supply Current (V_S)	No Load, V_{IN} = 20V		57	76	µA

QUICK START PROCEDURE

Demonstration circuit 2839A is easy to set up to evaluate the performance of the LTC6115.

A high voltage supply (5V to 100V, max 2A) is required to test the full input range of the LTC6115. A separate 2.7V to 5.5V source is required for the voltage sense supply.

If available, an electronic load capable of sinking up to 2A at 100V may be used to test input range as well.

USE CAUTION WITH HIGH VOLTAGES!

If using on its own (not as Linduino shield):

Refer to Figure 1 for proper measurement equipment setup and follow the procedure below.

1. Place jumpers in the following positions:

   JP1 and JP2

   Position DIV to use simulated V_{SENSE} = V^+/1001 as current sense input

   JP3

   Install jumper, to tie current sense and voltage sense inputs to the same source

   JP4

   Position 50V/V for OUTI voltage gain of 50 on current sense input V_{SENSE}

   JP5

   Position EX_VS for external V_S supply

   JP6 and JP7

   Position 2V/V for gain = +2 on OUTV

2. With power off, connect the high voltage (5V to 100V) input/power supply to INPUT_ISENSE and/or INPUT_VSENSE turrets and a GND turret. 12V is a good starting point.
3. With power off, connect a lower-voltage (2.7V to 5.5V) supply to the EXT_VS and GND turrets. 5V is a good starting point.
4. Connect a DMM on voltage setting, mV range, to the OUT_ISENSE turret.
5. Connect a DMM on voltage setting, mV range, to the OUT_VSENSE turret.
6. Power up the system. If using $V^+ = V_{IN}$ = 12V, OUTI and OUTV should both be around 600mV.
7. Increase the input voltage and observe as the output climbs to 5V max for both channels at $V^+ = V_{IN}$ = 100V.

Optional: Electronic Load Capable of Sinking Up to 2A at 100V

8. Turn off both power supplies. Connect the electronic load to the LOAD_ISENSE and GND turrets and set its current and voltage limits. A current limit of 240mA and a voltage limit of 105V on the electronic load are good starting points.
9. Move both jumpers **JP1 and JP2** to position RS to use the 50mΩ sense resistor for current sense input. Keep all other jumpers in the same positions as in step 1.
10. Power up both supplies. If using $V^+ = V_{IN}$ = 12V and I_{LOAD} = 240mA, OUTI and OUTV should both be around 600mV.
11. Increase the current limit on the electronic load to 2A. Increase the input voltage and observe as the output climbs to 5V max for both channels at $V^+ = V_{IN}$ = 100V and I_{LOAD} = 2A.

QUICK START PROCEDURE

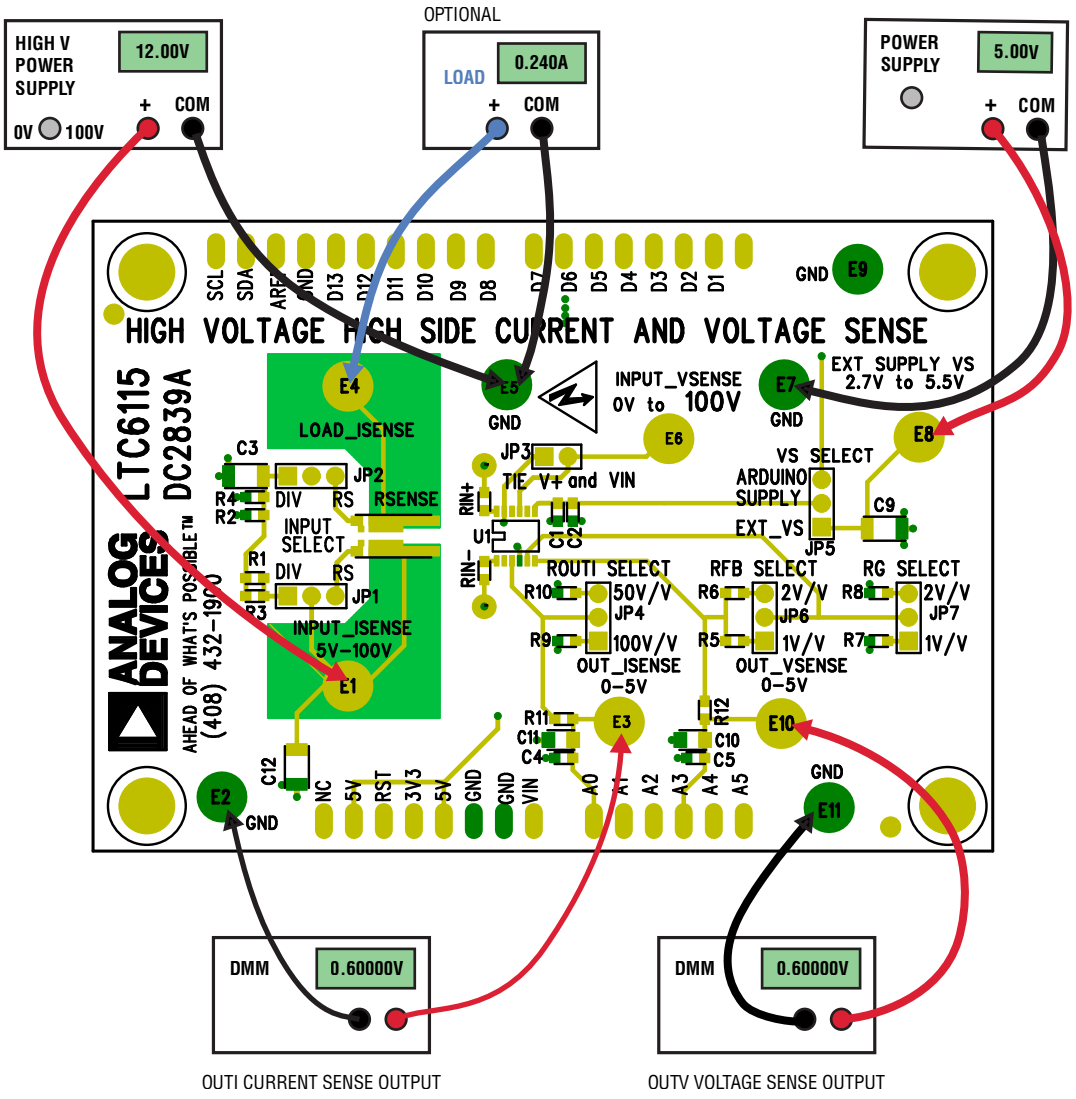


Figure 1. Proper Measurement Equipment Setup for Standalone (Non-Linduino-Shield) Use

QUICK START PROCEDURE

If using as Linduino shield:

Refer to Figure 3 for proper measurement equipment setup and follow the procedure below.

A Linduino sketch for DC2839A is available in the Linduino sketchbook, which can be downloaded at https://github.com/analogdevicesinc/Linduino.

1. Place jumpers in the same positions as step 1 for non-shield use, with one exception:

   JP5

   Position ARDUINO SUPPLY for on-board 5V V_S supply

2. Insert DC2389A above disconnected Linduino board as a shield.
3. With power off, connect the high-voltage (5V-100V) input/power supply to INPUT_ISENSE and/or INPUT_VSENSE turrets and a GND turret. 12V is a good starting point.
4. Connect Linduino to computer with USB cable.
5. Make sure Linduino is loaded with the DC 2839A Linduino sketch. Instructions on how to load sketches can be found in the DC2026C Demo Manual.
6. When the sketch is successfully loaded, open the serial monitor on the computer. The prompt in Figure 2 should appear on the console. **Note: I Gain 2.50 V/A is equivalent to 50 V/V for R_{SENSE} = 50mΩ (default).**
7. Power up the high-voltage supply. Enter option 1 at the console to take a single reading. If using $V^+ = V_{IN}$ =12V, OUTI will be 240 mA and OUTV will be 12V, both within ± 3% error.
8. Select option 5 to read data continuously. When prompted, enter “100” for 100 samples.
9. Increase the input voltage and observe as the console outputs climb along with the inputs for both channels at $V^+ = V_{IN}$ = 100V.

```
******************************************************************
* LTC6115                                                        *
*                                                                *
* This program demonstrates how to work with the LTC6115.        *
*                                                                *
* Set the baud rate to 115200 and select the newline terminator.*
*                                                                *
******************************************************************
Demo Board Name: DC2839A
Product Name: LTC6115

*************************
1  - Convert and Read V and I (Single Sample)
2  - Change V Gain (Current setting: 2.00 V/V)
3  - Change I Gain (Current setting: 2.50 V/A)
4  - Change Sampling Period (Current setting: 1000ms)
5  - Begin Continuous V and I Sampling Conversion Readings (For
Specified # of Samples)
6  - Stop Sampling

Enter a command:
```

Figure 2. Linduino Prompt

QUICK START PROCEDURE

Optional: Electronic Load Capable of Sinking Up to 2A at 100V

10. Turn off power supply and disconnect board from Linduino. Connect the electronic load to the LOAD_ISENSE and GND turrets and set its current and voltage limits. A current limit of 240mA and a voltage limit of 105V on the electronic load are good starting points.
11. Move both jumpers **JP1 and JP2** to position RS to use the 50mΩ sense resistor for current sense input. Keep all other jumpers in the same positions as in step 1.
12. Reconnect board to Linduino and power up the supply. Enter option 1 at the console to take a single reading. If using $V^+ = V_{IN}$ = 12V and I_{LOAD} = 240mA, OUTI will be 240mA and OUTV will be 12V, both within ±3% error
13. Select option 5 to read data continuously. When prompted, enter 100 for 100 samples.
14. Increase the current limit on the electronic load to 2A. Increase the input voltage and observe as the console outputs climb along with the inputs for both channels at $V^+ = V_{IN}$ = 100V and I_{LOAD} = 2A.

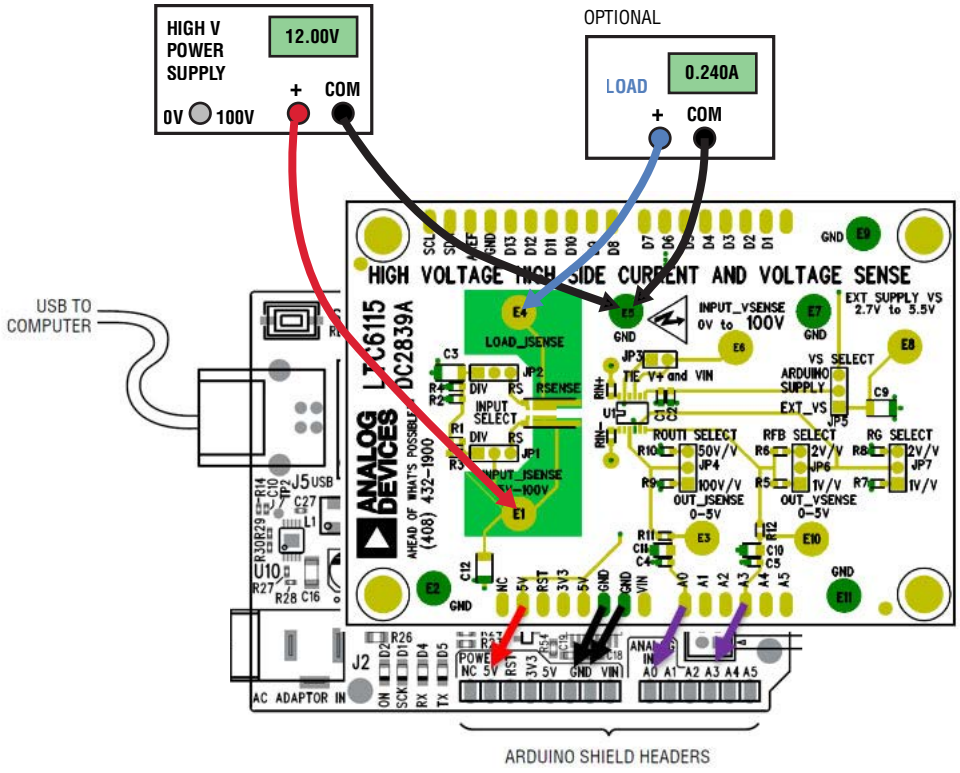


Figure 3. Proper Measurement Equipment Setup for Linduino Shield Use

OPERATING PRINCIPLES

Jumper Table

JP	PROPERTY	POSITION 1	POSITION 3
JP1, JP2*	Current Sense Input Selection	$V_{SENSE} = V^+/1001$ R Divider Input	$V_{SENSE} = I_{LOAD} \times R_{SENSE}$ R_{SENSE} = 50mΩ Default
JP3	Ties V_{IN} to V^+	V_{IN} Tied to V^+	N/A
JP4	OUTI Gain	100V/V 10kΩ R_{OUTI}	50V/V 4.99kΩ R_{OUTI}
JP5	V_S Supply Source	EXT_VS 2.7V to 5.5V External Supply	ARDUINO SUPPLY 5V Onboard Supply
JP6, JP7*	OUTV Gain	1V/V (Buffer)	2V/V

* Paired jumpers must BOTH be moved together for correct functionality.
For detailed explanations of each jumper setting, please see the subsequent section, Operating Principles.

DC2839A has two inputs, one for the voltage sense and one for the current sense. Jumper JP3 ties the voltage sense (V_{IN}) and current sense (V^+) lines together by default. Removing the JP3 connector allows the two inputs to be independent, which may be useful for taking advantage of the different input voltage ranges of the voltage sense (0V to 100V) and current sense (5V to 100V).

When DC2839A is used as a shield for a Linduino or Arduino-equivalent controller board, the two outputs OUTI and OUTV are connected to pins 1 and 4, respectively, of the Arduino analog header J2 near the bottom right of the board. These pins go to analog inputs A0 and A3, respectively, of the ATmega 328/P's on-chip 10-bit ADC. Footprints for RC filter components (R11, C4, C11 for OUTI; R12, C5, C10 for OUTV) located immediately before the analog input header pins are provided.

CURRENT SENSE

DC2839A's current sense is a typical high side current sense architecture as shown in Figure 4.

The current to be measured, I_{LOAD}, passes through sense resistance R_{SENSE} to create an input voltage V_{SENSE}. The internal current sense amp A1 replicates this V_{SENSE} across R_{IN}^- to keep the voltage at –IN and +IN nearly equivalent.

The current created by establishing V_{SENSE} across R_{IN}^- cannot enter the high impedance input –IN, so it flows through the internal MOSFET and becomes the output current sourced by OUTI. This output current is then converted back to voltage V_{OUTI} by passing it through load resistance R_{OUT}.

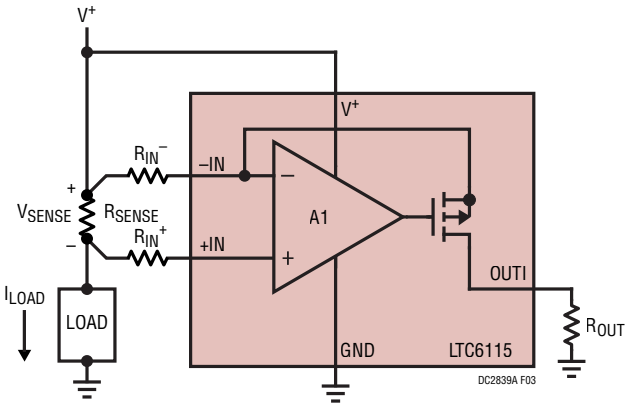


Figure 4. Current Sense

OPERATING PRINCIPLES

An optional R_{IN}^+ is provided to cancel I_{BIAS} and to balance any thermoelectric offset voltage at the input generated by temperature gradients.

The combination of R_{SENSE}, R_{IN}^-, and R_{OUT} determines the transimpedance (V/A) coefficient for converting input current I_{LOAD} to output voltage V_{OUTI}. Equivalently, R_{IN}^- and R_{OUT} set the voltage gain (V/V) coefficient for converting input voltage V_{SENSE} (applied or developed at the input between R_{IN}^- and R_{IN}^+) to output voltage V_{OUTI}.

Current Sense Gain/Transimpedance

DC2839A's current sense gain or transimpedance may be easily modified by selecting a different value for output resistance R_{OUT}. As explained below, a default 4.99kΩ R_{OUT} sets the transimpedance at 2.5V/A, which corresponds to 50V/V voltage gain.

The transimpedance is determined by,

$$\frac{V_{OUT}}{I_{LOAD}} = \frac{R_{OUT} \bullet R_{SENSE}}{R_{IN}}$$

For the default component values of DC2839A,

$$\frac{V_{OUT}}{I_{LOAD}} = \frac{4.99k\Omega \bullet 50m\Omega}{100\Omega} = \frac{2.5V}{A}$$

The current sense's voltage gain is set according to,

$$A_{V,\,OUTI} = \frac{R_{OUT}}{R_{IN}}$$

For the default component values of DC2839A,

$$A_{V,\,OUTI} = \frac{4.99k\Omega}{100\Omega} = \frac{50V}{V}$$

Current Sense Gain Configuration

On DC2839A, shifting jumper **JP4** from 50V/V to 100V/V changes the gain to a transimpedance of 5V/A, or equivalent voltage gain of 100V/V. With default 50mΩ R_{SENSE} and gain of 100V/V, maximum I_{LOAD} is now 1A.

Moving JP4 changes R_{LOAD} from the default 4.99kΩ R10 to the 10kΩ R9. Other values of R_{LOAD} may be stuffed in R9 or R10 as desired. Choice of R_{LOAD} may affect ADC driving performance, depending on the input impedance of the subsequent stage.

Current Sense Input

Jumpers JP1 and JP2 together select the input source for the high side current sense. When JP1 and JP2 are **both** on the RS setting, the input to the current sense channel is the voltage produced by passing I_{LOAD} through the default 50mΩ 1%1W rated 4-terminal R_{SENSE}.

The R_{SENSE} footprint on DC2839A is configured for Kelvin sensing for long-edge 2-terminal and 4-terminal sense resistors. It also accommodates both 2512 and 1206 footprints if sense resistors with higher power ratings are needed. Be sure to select a sense resistor with a healthy power rating margin above the maximum expected $I_{LOAD}{}^2R_{SENSE}$ wattage.

Due to the difficulty of sinking precise, high currents in a test environment, and the small (less than 500mV) but high-common-mode input signals required, a simulated current sense input can be selected by shifting both JP1 and JP2 to DIV.

This simulated input is created by dividing V^+ down via a resistor divider R1 and R2, where the voltage across R1 becomes the V_{SENSE} input. By default, R1 = 1kΩ and R2 =1MΩ on DC2839A; simulated input V_{SENSE} is V^+/1001. Optional spaces labeled R3 and R4 are provided in parallel with R1 and R2, respectively, for additional flexibility.

OPERATING PRINCIPLES

Current Sense Power Supply

DC2839A's high side current sense draws power from the 5V to 100V current sense pin V^+.

Bypass capacitors are optional for the high voltage supply/input, since the LTC6115 has internal bypass capacitance. If desired, space is provided in C3 and C12 to stuff high voltage (>200V rated) bypass capacitors.

VOLTAGE SENSE

DC2839A's voltage sense is configured for noninverting gain, as shown in Figure 5. V_{IN} is divided down by 40 at the input and then (optionally) gained up by external resistors R_G and R_{FB}.

Voltage Supply and Input Voltage Range

The maximum voltage that can accurately be monitored on the V_{IN} pin is limited by the supply voltage, V_S, as it affects the input common mode of the internal operational amplifier A2.

The full 100V range on V_{IN} is available with a supply voltage of 4V or more. With a 3V supply, it is recommended to keep V_{IN} below 60V to maximize precision. Beyond these recommended V_{IN} voltages at each supply voltage, accuracy will degrade.

At lower V_{IN} voltages, external resistors can be used to add gain and maximize use of amplifier A2's rail-to-rail output.

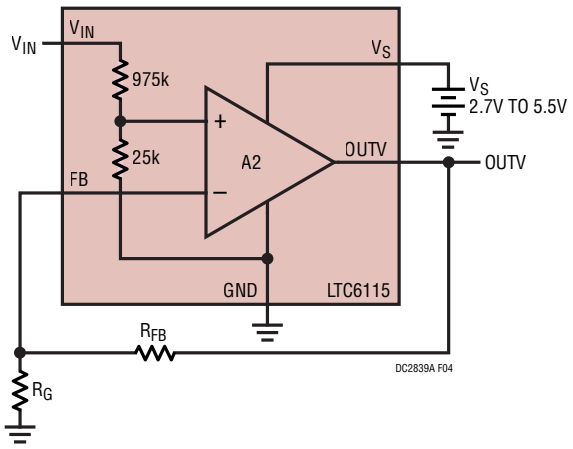


Figure 5. Voltage Sense with Optional Gain Configuration

OPERATING PRINCIPLES

Voltage Sense Gain

Jumpers JP6 and JP7 together control the voltage gain of this channel, with JP6, labeled RFB, selecting the feedback resistance R_{FB}, and JP7, labeled RG, the resistance to ground R_G.

The voltage gain of this circuit is set by,

$$A_{V,\,OUTV} = \frac{1}{40} \bullet \left(1 + \frac{R_{FB}}{R_G}\right)$$

The default configuration is as a unity gain buffer, labeled as 1V/V on both JP6 and JP7, with R_{FB} = 0Ω and R_G unstuffed. For voltage gain of 2V/V, shift **both** JP6 and JP7 to the 2V/V position to select for $R_{FB} = R_G$ = 10kΩ.

Voltage Supply Source Selection

Connecting jumper JP5 at the default EXT_VS setting chooses an external independent power supply connected to turret EXT_VS. Shifting JP5 to the ARDUINO SUPPLY setting when DC2839A is used as a Linduino or Arduino-equivalent shield powers V_S from the controller board's 5V supply via the analog supplies header in the lower left corner of the board.

OVERALL

Multiple ground turrets have been provided so that every source/signal has a convenient nearby ground.

Please refer to the schematic diagram provided with the demo board files for the circuit details.

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