International
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DESIGN TIP

DT 92-6

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CURRENT SENSING WITH THE IR2130

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Introduction

The IR2130 High voltage MOS gate Driver IC provides a convenient and cost effective gate drive solution for applications requiring a three phase bridge configuration. It comprises three high side and three low side referenced drive channels and has been has been targeted at applications that include:

- WM AC Motor Drives,
- Six Step AC Motor Drives,
- UPS.

The IR2130 has features added to enhance its performance in these applications. These features include:

- Fault indicator output,
- Over current trip input,
- Current signal amplifier.

It is the use of this third feature, the current signal amplifier, that is the subject of this paper.

Amplifier Uses:
The current signal amplifier has been included so that the current in the return leg of the DC supply of the three phase bridge may be monitored. A typical circuit configuration is provided in the IR2130 data sheet.

This signal is amplified by the ratio of the feedback resistors and output on the VCaO pin of the IR2130. The details of the amplifier connection are shown in Figure 3 of International Rectifier Application Note AN-985.
The shape of the current seen in the DC link will depend on the switching topology used for the three phase bridge. Two such topologies are the “Six Step Inverter” and the “Pulse Width Modulated Inverter”. Suffice to say that for reasonable load levels at moderate to high power factors the DC link current will always be a positive value. Any negative current passed back through the free wheeling diodes in the bridge due to the lagging current will be absorbed in the bridge and not appear in the DC link.

At light or low power factor loads the negative current levels will begin to exceed the positive demands in the bridge and a net negative current will flow in the DC link. The same will occur if the load is caused to regenerate back into the system.

Amplifier Limitations:
The recommendations for the operating limits of the internal current amplifier as specified in the data sheet are as follows:

V_S	(Low Side Drive Return)	-5 to +5 V
V_{CA}	(Amplifier Inverting Input)	0 to 5 V
V_{CAO}	(Amplifier Output Voltage)	0 to 5 V
I_{SRC}	(Amplifier Output Source Current)	2A
I_{SINK}	(Amplifier Output Sink Current)	0.5 mA

From these figures it is obvious that the output of the amplifier will not provide a negative voltage. This means that any negative current excursions in the DC link through the current sensing resistor will not appear at the output of the amplifier. This loss of information is further compounded by a characteristic of the amplifier that is not obvious from the data sheet. A recovery delay exists in the current sense amplifier operation as the input signal changes from a negative to a positive value.

The loss of negative input signals and the recovery delay of the amplifier is illustrated in Figure 1 where a triangular input was used as an example. The length of the delay is related to the dv/dt at the zero crossover of the input signal. As described earlier, negative inputs to the current sense amplifier are possible at light and low power factor loads. These negative excursions of current will be lost by the current amplifier.

Solution:
The recovery delay of the amplifier is due to the Vs input pin to the amplifier saturating when a negative voltage is applied . The charge accumulated requires time to be removed or dissipated

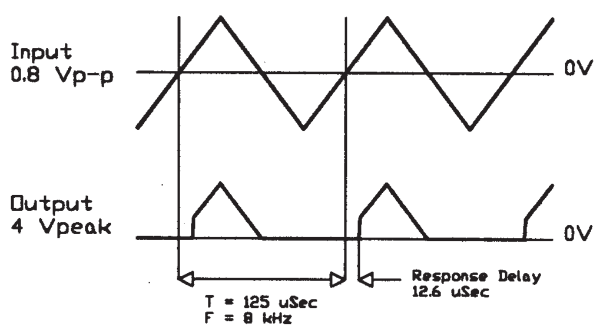

Figure 1. **Current Amplifier Operation with Triangular Waveform Input**

before the amplifier will begin to function correctly. The only method to stop this recovery delay time is to inhibit the Vs input voltage from going negative.
The input voltage will generally be of a small magnitude (less than 1 volt) since it is desirable to minimize the losses across the current sensing resistor and not introduce excessive voltages that will upset the drive circuitry. Such a small voltage signal is unsuitable for diode clipping.

Method 1:
The signal to the non-inverting input to the amplifier must be inhibited from having a negative value. If a differential amplifier is used with a voltage reference to shift the effective zero current reference input signal, the output will appear as an amplified version of the input signal, offset by some positive voltage The circuit for this solution is shown in Figure 2.

The relevant calculations for the selection of components for the given circuit are given in the Appendix. It can be seen that the choice of components is limited by the total amount of resistance allowed in the gate

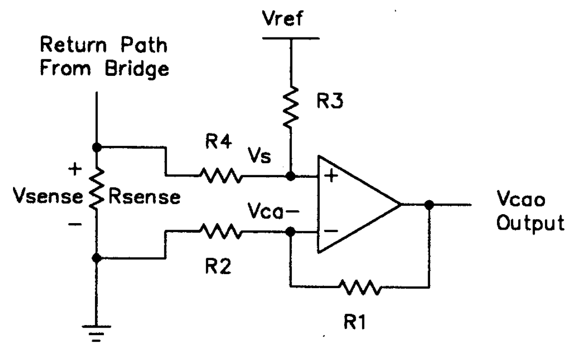

Figure 2. **Differential Amplifier with Voltage Offset**

loop, and the maximum current that can be sourced by the internal amplifier.

Method 2.
As stated in Method 1, the signal to the non-inverting input of the amplifier must be inhibited from having a negative value. This can be achieved by only allowing the positive components of current to pass through the sense resistor.

Since the positive components of current in the three phase bridge pass through the switching devices, and the negative components pass through the free wheeling diodes, it is a relatively simple operation to separate

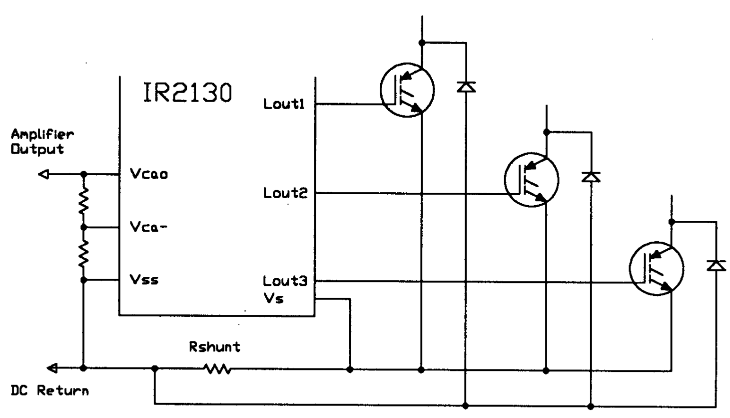

Figure 3. **Measurement of Positive Current Components in the DC Link**

them. The circuit in Figure 3 shows an implementation of this technique in a bridge that utilizes IGBTs. When MOSFETS are used as the switching devices an additional diode is required in series with each MOSFET to negate the internal body-drain diode. This is illustrated in Figure 4

Method 3:
A variation on Method 2 that may have advantages in respect to component count and cost in a MOSFET bridge is shown in Figure 5. The positive components of DC link current are passed through the shunt resistor by a diode. Negative current components are blocked by the shunt resistor diode and forced through a second rated parallel diode. These diodes do not have to be high voltage rated, but will have to carry the Full DC link current.

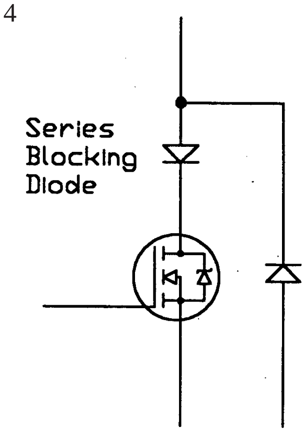

Figure 4. **MOSFET Connection for Separation of Positive and Negative Current Components**

Conclusion:

The IR2130 has an internal current signal amplifier designed to monitor the current flowing in the DC link. The amplifier provided has limitations in regard to the range of input signals it will operate with and poor response delay from a negative input signal. Improving the performance of the amplifier is awkward since the input pin on the IC for the non-inverting input to the amplifier is also the gate return connection for the drives to the low side devices.
Three solutions have been presented that alleviate the performance limitations of the amplifier and will improve the functionality of the IR2130 in applications where accurate current sensing of the DC link is required.
Method 1 enables the use of the total link current, including negative current components. Methods 2 and 3 allow only the positive components of DC link current to be passed through to the IR2130 internal current amplifier.

Appendix 1 Component Selection

When selecting components to use with the internal current amplifier the following design guidelines should be followed.

- The maximum value of resistor that can be inserted in the gate return path is 47 Ohms. Larger values than this may affect the switching performance of the device.
- The maximum output current of the amplifier is 2mA under worst case conditions.

Consider the circuit configuration shown in Figure 2. The gain of the non inverting amplifier stage is:

$$\frac{VCaO}{Vs} = 1 + \frac{R1}{R2} \qquad \textbf{(1)}$$

The signal at the VSO pin may be defined by the equation:

$$VS = Vsense + (Vref - VSenSe) \times \frac{R4}{R3+R4} \qquad \textbf{(2)}$$

Combining equations (1) and (2) gives:

$$VCao = Vsense \times (1+\frac{R1}{R2}) + [(Vref \sim Vsens) \times \frac{R4}{R3+R4}] \times (1+\frac{R1}{R2})$$

If the conditions R1 = R3 and R2 = R4 are true, then the last equation collapses to:

$$VCao = Vref + \frac{R1}{R2}$$

Using the design guidelines sets the range of resistor values that may be chosen. The 2mA current limit sets a minimum a minimum for the resistance sum R1 + R2. -This limit is defined by:

$$Ilimit = \frac{VcaO(max)}{R1+R2}$$

Ilimit = 2mA, Vcao(max) = 5V

This means that R1 + R2 > 2.5 kΩ. R2 is limited to 47 Ohms and R1 > 2.45 kΩ. This gives a gain in the circuit of R1/R2 = 52. If the output of the amplifier is in the range [0;+5V], then the offset could be 2.5 V, giving an allowable output voltage variation of +/-2.5V. The maximum variation of the input voltage is thus +/-50mV. This small signal level is possible with commercially available shunts that are low inductance to reduce noise from power device switching. It does mean however that the internal current trip function of the IR2130 cannot be used, as it has an internal 0.5V trip point. Care should be taken when using small input signal levels as the data sheet specification for the amplifier offset voltage is 10mV. An offset adjustment may need to be included in the circuit.

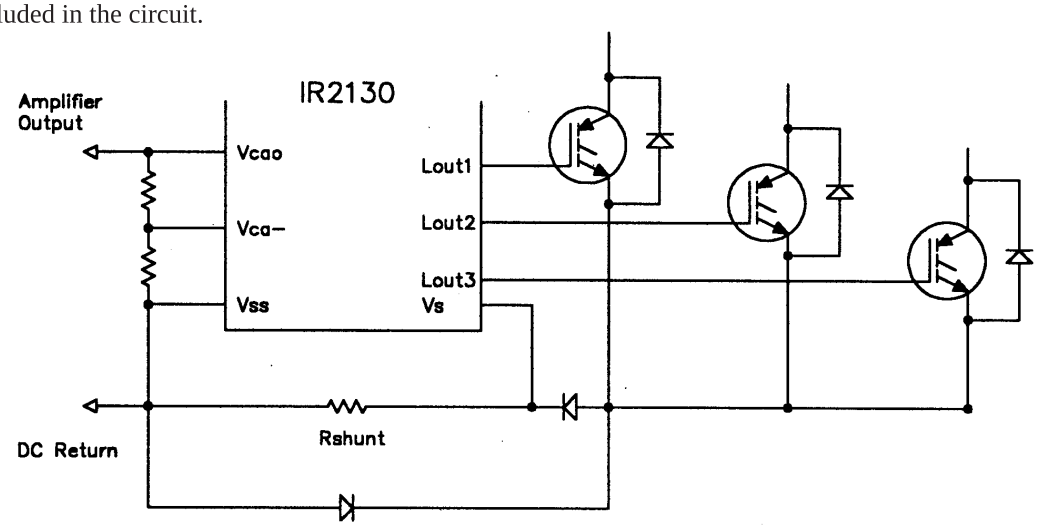

Figure 5. **Current Sense Blocking Diode**

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