Isense Input of the ADMCF328

ANF32X-52

Table of Contents

Summary

This paper presents some guidelines regarding the current sense signal of ADMC(F)328 motor controller . First, its functionality will be explained and then some hardware guidelines will be recommended.

1 Description of current sense signal

On the ADMC(F)328, pin 12 is called I_{SENSE} and is used to measure currents. Suppose a certain current must be measured. A shunt resistor may be used to capture the current and transform it into a voltage. Measuring this voltage with an Analog to Digital converter offers a direct estimation of the current. The problem is the maximum voltage obtained on these shunts is very low, below the common range of the input voltage of A/D converters. For this reason, an inverting amplifier has been added to the ADMC(F)328 . In addition, a sample and hold amplifier that samples the current sense signal on the falling edge of the PWMSYNC pulse is provided. The output of the inverting amplifier is used also to generate a PWMTRIP signal that protects the inverter in the case of an overcurrent. This function is realized by further amplifying the signal and comparing it with a certain threshold voltage.

One of the I_{SENSE} applications is the measurement of the DC bus current in an inverter, especially when a brushless DC motor with trapezoidal back-emf has to be driven. Fig.1 presents the schematic of this configuration.

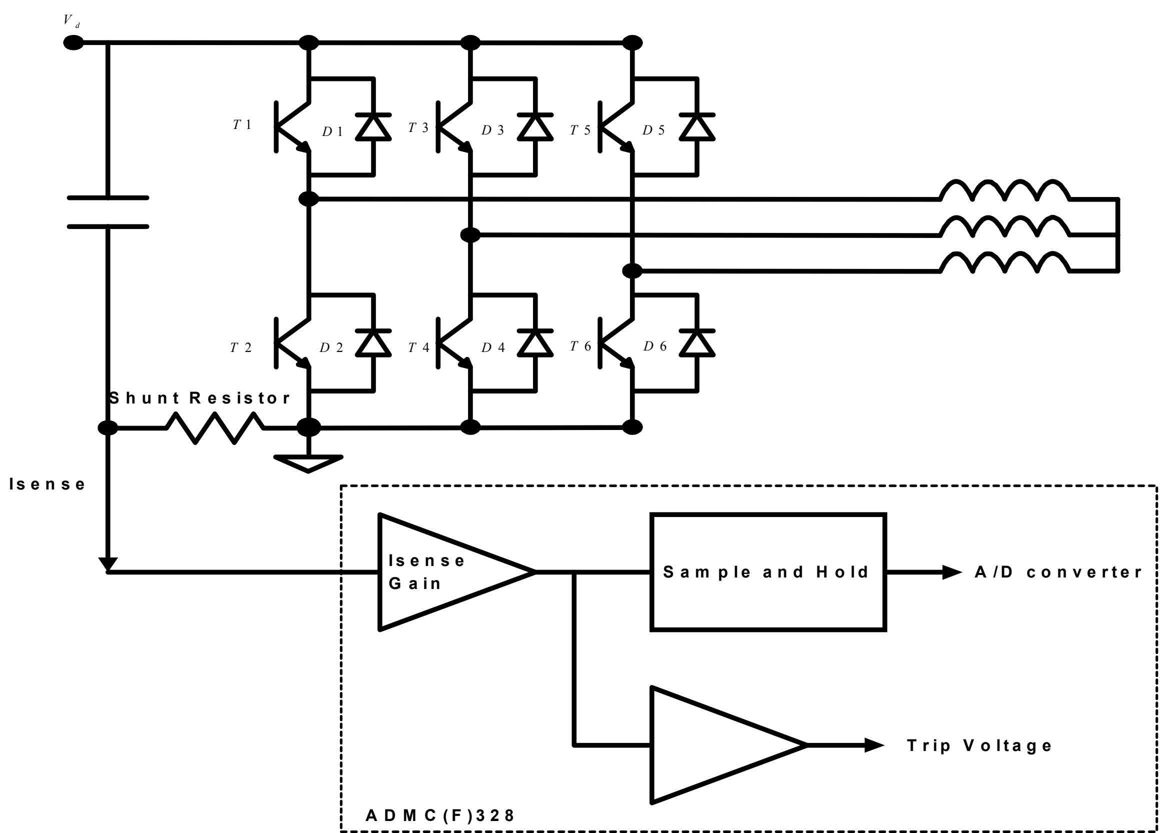

Fig.1. Typical Power Inverter Topology for Trapezoidal Brushless DC Motor

In this case, the current through this shunt resistor will have always the same direction, from the power devices to the dc power supply. The I_{SENSE} pin corresponds to the channel 3 of the A/D converter. After the associate register ADC3 is read and modified accordingly (see application note ANF32X-05, ADC System on the ADMCF32X) , the conversion of the voltage applied at its internal input, after the sample and hold circuit will be:

$$\frac{V_3}{VADC_{\max}} = \frac{R \cdot I \cdot AmplifierGain_{Isense}}{VADC_{\max}} \tag{1}$$

where

V_3 =the voltage applied at the internal input of the A/D converter, always positive,

$VADC_{\max} = 3.5V$, the maximum voltage that may be applied at the input of the A/D converter,

R =the shunt resistor used to measure the current,

I =the current to be measured,

$AmplifierGain_{Isense}$ =the gain of the internal inverting amplifier. From the data sheet, it is -5.1 typical.

If one decides to use a certain scaling factor $I_{\max}$, the value read from the A/D converter has to be modified using the following expression determined from (1):

$$\frac{I}{I_{\max}} = \frac{V_3}{VADC_{\max}} \cdot \frac{VADC_{\max}}{R \cdot AmplifierGain_{Isense} \cdot I_{\max}} \tag{2}$$

In order to have an accurate measurement of the current using the A/D converter, the following steps must be followed (see application note ANF32X-05, ADC System on the ADMCF32X):

-choose the external timing capacitor on the ICONST pin to ensure maximum resolution,

-tune the internal current source using the internal register ICONST_TRIM,

-calibrate the A/D converter using the internal reference voltage,

-measure the offset on the I_{SENSE} channel.

2 PWM Shutdown using Isense

In the event of external fault conditions, it is essential that the PWM system be instantaneously shut down. On ADMC(F)328 there are two methods to sense a fault condition: low level on the $\overline{PWMTRIP}$ pin and by means of the I_{SENSE} pin. When the voltage of I_{SENSE} goes below I_{SENSE} trip threshold, a shutdown will be generated in the same manner as a negative edge on pin $\overline{PWMTRIP}$. The trip threshold is called V_{TRIP} in the data sheet and varies between *-0.64 V* and *–0.45 V*, with *-0.53 V* typical value.

The mathematical relation between the current I_{TRIP} at which the protection will occur and V_{TRIP} is:

$V_{TRIP} = R \cdot I_{TRIP}$.

Noise entering the controller through the I_{SENSE} pin can be very damaging, because it may cause fault shutdowns very frequently and wrong A/D conversions. A schematic that diminishes the noise influence is presented in Fig.2.

It may be observed that a capacitor *C* is placed in parallel with the shunt resistor *R* to act as a filter and then, down the line, another low pass filter *R1*, *C1* is placed. Because the input impedance of the I_{SENSE} internal circuit is around 2.5 KΩ, the resistor R1 should be very low. Also, the filter cut frequency should be sufficiently high, in order to leave enough bandwidth for the current controller that is eventually implemented in the motor control program. For example, if the shunt resistor *R* is 0.1 Ω, the following components may be used: *C* = 0.1 µF, *R1* = 47 Ω and *C1* = 0.1 µF.

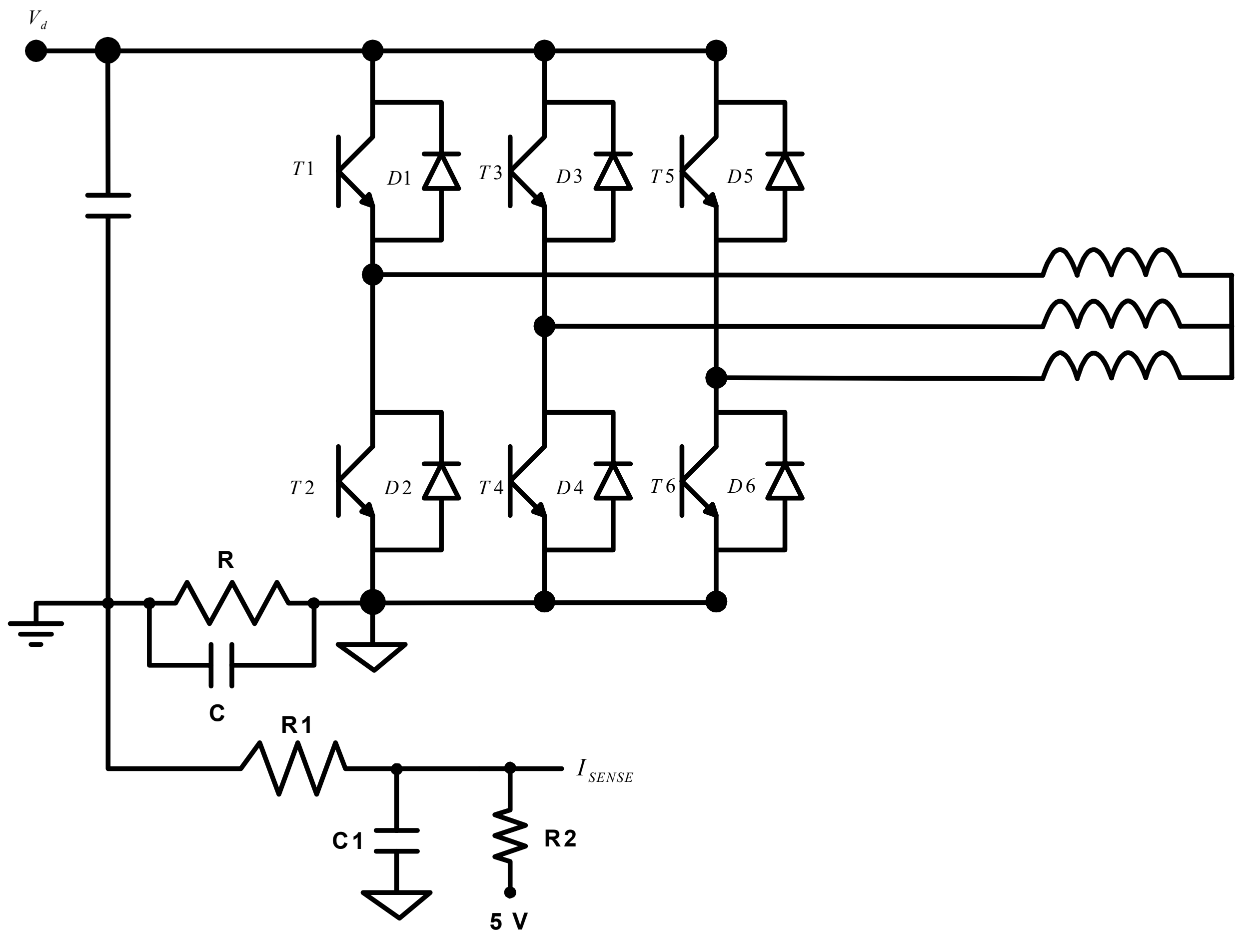

Fig.2. Recommended I_{SENSE} circuit

However, in an inverter environment there are situations when the proposed filtering may still not be sufficient and for this reason, an additional pull up resistor *R2* has been introduced. The current pumped through this resistor from the 5 V source creates an offset on the I_{SENSE} pin and in this way the possibility of spurious PWM shutdowns is further reduced. The recommended value is 1.8 KΩ. The downside of *R2* is this added offset increases somewhat the value of I_{TRIP} .

Another approach is the one presented in Fig.3. Instead of using the I_{SENSE} related PWM shutdown system, the protection offered by $\overline{PWMTRIP}$ pin is utilized. It may be observed that the circuit for I_{SENSE} pin is considered only to measure the current through the shunt resistor *R* and contains the resistor *R1*, the diode *D* and the pull-up resistor *R2.* When the voltage on the shunt resistor *R* goes below the forward voltage of the diode *D* (around 600 mV depending on diode type), the I_{SENSE} pin will be clamped to this voltage. The resistor *R1* limits only the current that will pass through the diode in the case of a shutdown. *R2* has the same role as in the previous schematic that is to diminish the noise influence in producing a PWM shutdown. The circuit related to $\overline{PWMTRIP}$ pin behaves as follows: when the voltage on the shunt resistor *R* is lower than the base emitter voltage of the transistor *T* (around 600 mV depending on transistor type), the transistor is turned off and the voltage at the $\overline{PWMTRIP}$ pin is 5 V because of the pull up resistor *R5*. Of course, the filter *R6, C6* protects this pin against noise. When the voltage on the shunt resistor *R* becomes lower than the base emitter voltage of *T*, the transistor begins to conduct and will put $\overline{PWMTRIP}$ at ground, causing the PWM instantaneous shutdown.

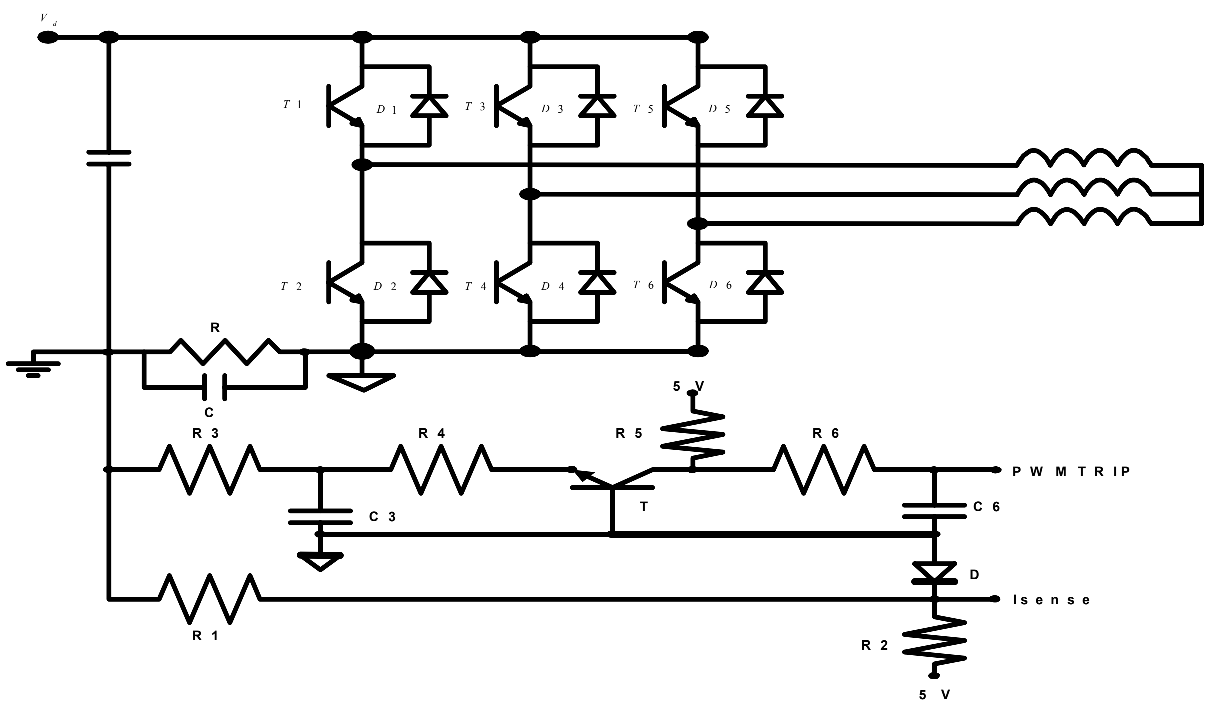

Fig.3. Another schematic for I_{SENSE} circuit

This schematic has the advantage that no filter is placed in the I_{SENSE} circuit and therefore higher bandwidths in the current loops may be obtained. The current value at which the PWM shutdown protection will intervene is determined now by the base emitter voltage V_{BEsat} of the transistor *T* and will be:

$$I_{TRIP} = \frac{V_{BEsat}}{R}.$$

For example, if the shunt resistor *R* is 0.1 Ω, then the following components may be used: *R1* = 47 Ω, *R2*= 1.8 KΩ, *R3* = 22 Ω, *C3* = 100 nF, *R5* = 15 KΩ, *R6* = 1.8 KΩ, *C6* = 220nF.

3 Hardware guidelines

Because of its sensitivity to noise, the board of the inverter should be carefully designed, following some basic rules:

-the shunt resistor *R* should be placed as close as possible to the power devices T2, T4, T6 (see Fig.2 and Fig.3) in order to minimize the inductance between various traces. The capacitor *C* should be placed as close as possible to the resistor *R*.

-the traces of the DC bus voltage and its ground should be placed one near the other.

-the power part of the inverter, that is the power devices, the 5 V and 15 V power supply, the power capacitors, should be separated from the digital components. The motor controller with its related components should be placed as far as possible from the power part. The link between the grounds of the two sectors should be very thin, in this way the trace will have higher impedance and will act as a filter. The trace from the shunt resistor to the other components of the discussed circuits should be near this ground trace. All these components should be placed as close as possible to the motor controller.

-Ground surfaces should be placed under the motor controller and on the opposite side of the board.