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EXPERIMENTAL CONSIDERATIONS ABOUT A THREE-PHASE GATE DRIVE IC USED IN A.C. MOTOR CONTROL

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Abstract. *The variable frequency drive (VFD) for AC induction, AC synchronous, brushless DC and AC motors, usually use three-phase IGBT inverter stage. The traditional method for IGBT command and over-current protection requires the following major components: 6 fast opto isolators, 2 fast Hall effect sensors or fast linear opto isolators, 2 comparators and 4 floating 15V power supplies. All the previous discrete circuits are eliminated with the IR2233 three-phase IGBT gate drive IC by International Rectifier.*
Keywords: *IGBT drive, three-phase inverter, over-current protections.*

Introduction

For correct variable-speed operation of three-phase ac machines, such as the ac induction motor or synchronous motors, it is necessary to supply the machine with a balanced set of three-phase voltages of variable frequency. The most convenient and traditional method of generating such variable-frequency ac voltages is through the use of pulse width modulation techniques. The frequency converter can be build up in many different ways, depending on the topology and flexibility of the system. One of the ways, which has become the most common, is the way illustrated below.

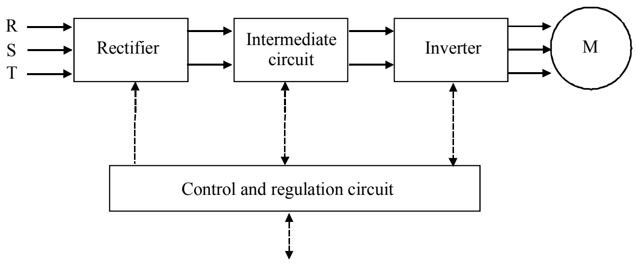

Figure 1. Block diagram for VFD of AC motors

As it can be seen at Figure 1 the system includes 4 basic blocks that are:

- a rectifier used to generate DC from the 1 or 3 phase distribution net;
- the intermediate circuit - incorporates the DC-link control. Different control-aspects can be taken into account, such as PFC, DC-chopping or stabilization;
- an inverter used to reproduce three controlled waveforms. In this case the output from the inverter is three 120-degree phase-shifted sine-shaped voltages.
- control-block - here all the necessary adjustment of the system are done. For the frequency converter this control-block controls the inverter to deliver the wanted waveforms to the motor, meaning the voltage to frequency ratio. [1]

1200V Three-Phase Gate Drive IC

Using the 1200V HVIC technology creates a new architecture for the gate drive circuits of a 460VAC three-phase inverter. The first product is the IR2233 that provides in a single chip all the circuits necessary to interface between the microcontroller and the three-phase IGBT power stage. [2]

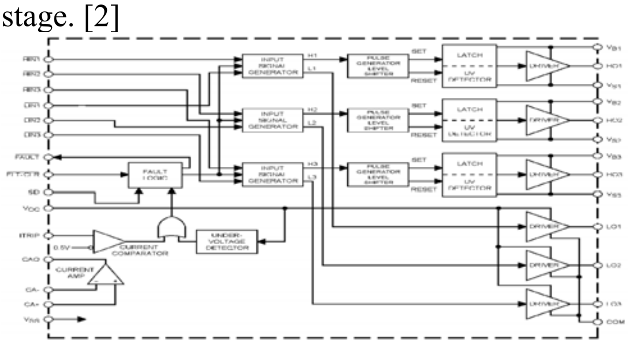

Figure 2. Functional blocks diagram

For most applications this circuit provides a simple, low cost, high performance solution to the gate drive requirements of most applications. The block diagram for the IR2233 is shown in Figure 2. The I.C. consists of six output drivers, which receive their inputs from the three input signal generator blocks each providing two outputs. The three low-side output drivers are driven directly from the signal generators L1, L2 and L3 but the high-side drive signals H1, H2 and H3 must be level shifted before being applied to the high-side output drivers.

An undervoltage detector circuit monitoring the VCC level provides an input to inhibit the six outputs of the signal generator circuits. In addition, there are individual undervoltage lockout circuits for the high-side outputs should any of the floating bias supplies fall below a predetermined level.

The ITRIP signal which can be derived from a current sensor in the main power circuit of the equipment (current transformer, viewing resistor, etc.) is compared with a 0.5volt reference and is then "OR-ed" with the UV signal to inhibit the six signal generator outputs.

A fault logic circuit set by the UV or ITRIP inputs provides an open drain TTL output for system indication or diagnostics. There is also an internal current amplifier. The current sense amplifier amplifies phase leg current from precision LEM sensor in the power return path. The two inputs (CA+, CA-) and the output (CAO) of the amplifier are available as external pins to simplify noise filtering. The current sense amplifier has a 15V/µsec slew rate and less than 10 mV offset.

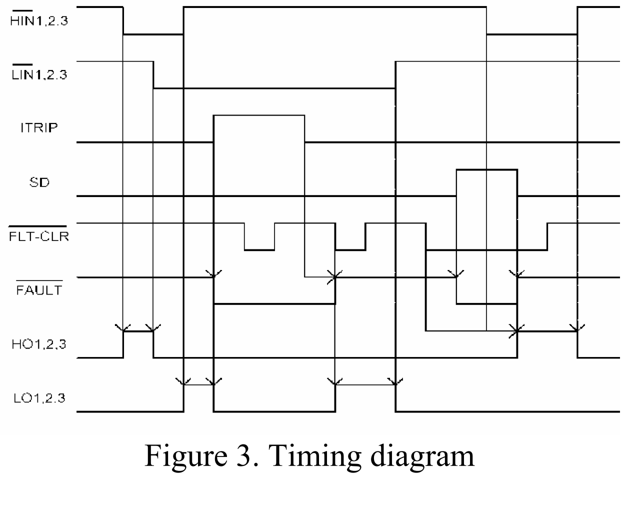

Figure 3. Timing diagram

Figure 3 shows the logic-timing diagram. The logic level shutdown is used to interface with the DSP board and the analog level shutdown is used to interface with local over-current or over-temperature sensing amplifier output. The FAULT pin is an open-drain output that turns on whenever fault conditions occur from SD, ITRIP and UVCC. The chip will stay off until the FLT-CLR pin is pulled low to clear the fault mode. The dead-time circuit is internally set to 200nsec dead time, which allows the system controller to have a high level of control flexibility. All the logic input pins (HIN and LIN) have a 300nsec filtering time and the shutdown pins (SD, ITRIP) have 400nsec blanking time. This allows the chip to operate in noisy environments. The monolithic chip is assembled in a customized 44-pin PLCC package. High voltage and low voltage pins are separated with missing pins taken out from the package to increase voltage creepage distance.

Experimental results

In the following section we present some experimental results witch illustrate the performances of the IR2233 circuit.

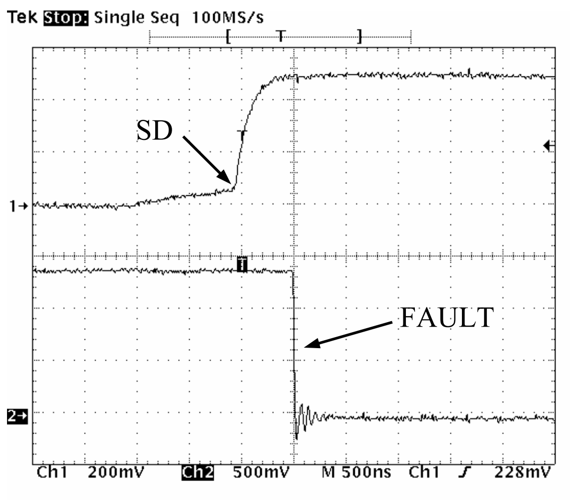

Figure 4. SD, FAULT signals

Figure 4 shows the FAULT pin turns on whenever fault conditions occur from SD. Figure 5 and 6 display fault conditions from UVCC. This UVCC is created when power supply circuits is turned off. Then when the voltage VBS is below 8.3V all six drivers is turned off as seen from Figure 5. The same FAULT pin signals this fault (Figure 6).

One of most common, and fatal, AC drive faults for IGBTs is the over-current condition. The three most common over-current modes is follows: Line-to-Line Short, Ground Fault and Shoot Through.

In both Line-to-Line and Shoot Through mode, the short circuit current flows from and to the DC bus capacitors. Therefore, a shunt resistor in the ground path can detect these over-current conditions. The voltage drop across low side viewing resistor proportional to load motor current is delivered to the ITRIP pin 14 of the IR2233 44-lead PLCC. This voltage is compared with 0.5V reference level (Figure 2).

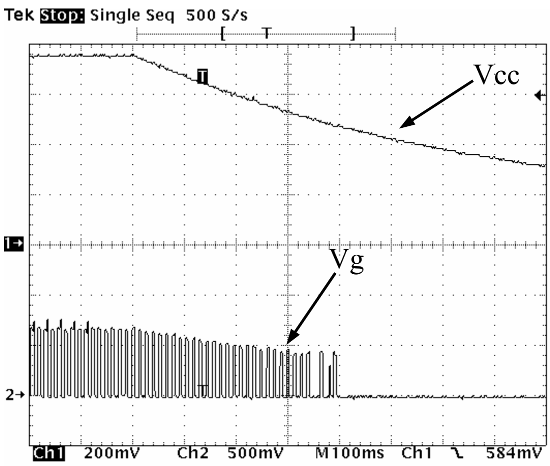

Figure 5. Ucc&Vg signals at UVCC protections

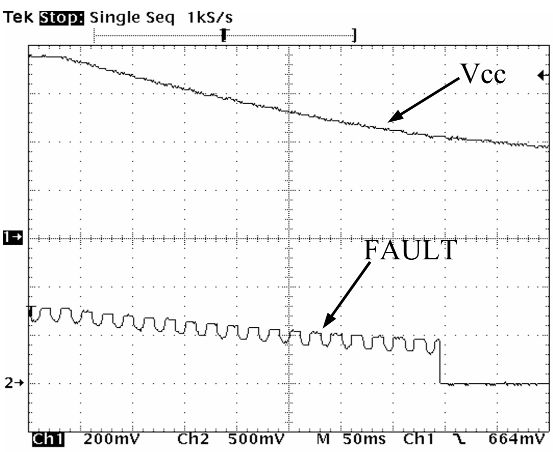

Figure 6. Ucc&FAULT signals at UVCC protections

However in the Ground Fault mode, the current flows from AC line input, through the positive DC bus and high side IGBT, to earth ground. The Ground Fault can detect by inserting a Hall Effect sensor or a linear opto isolator across the shunt resistor, as show in Figure 7. The protection circuit is then implemented by using fast comparator. The output of this comparator is delivered to the SD pin to initiate the shutdown of the gate signals. [3]

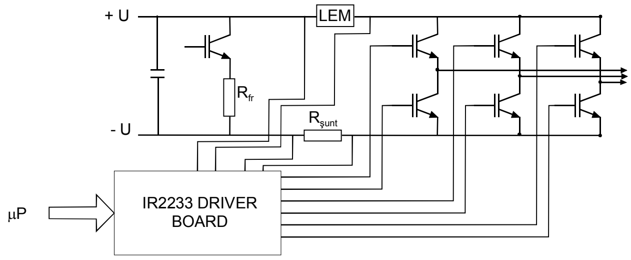

Figure 7. Sensors for over-current protection

The waveforms shown in Figure 8 illustrate the actions protection when over-current is detected in one DC bus.

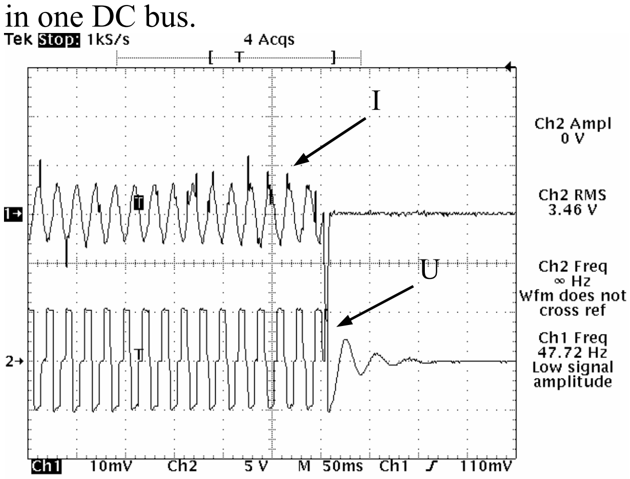

Figure 8. Over-current protection

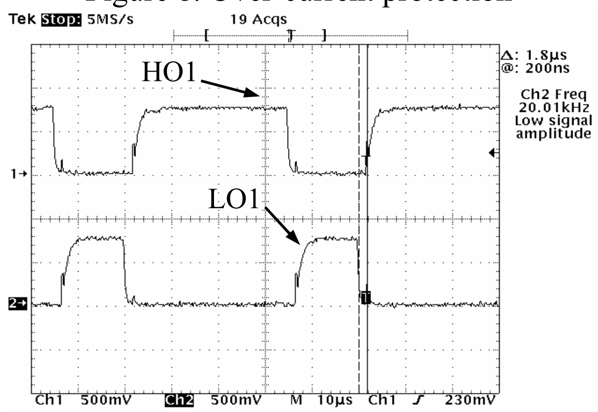

Figure 9. HO & LO si

In practice, because of the finite turn-off and turn-on times associated with any type of switch, it is necessary presence of a dead time in the switch-control signals. The IR2233 generated internally a time equal a 250 ns.

Figure 9 shows dead time of switch-control signals in same inverter leg. The value of this time is 1.8 μs because control board generates the dead time also. Figure 10 displays the motor line-to-line voltage and current. Figure 11 shows the practically scheme for three-phase IGBT inverter. The command of the inverter it makes with DSP board. The DSP used in this application is the new ADMC401 from Analog Device, it is a improvement of the well known in the motor driver market “ADMC” used in many motor driver applications.

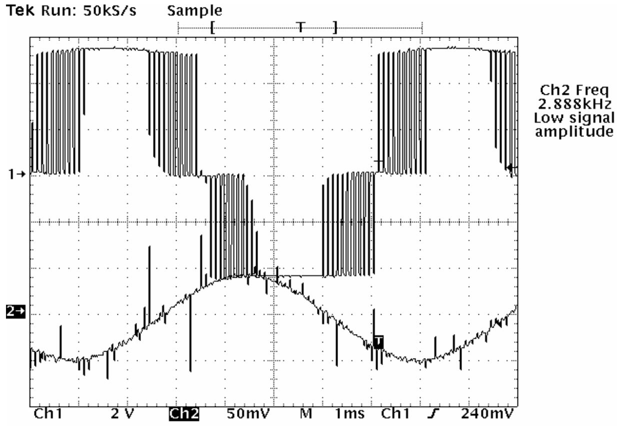

Figure 10. Motor line-to-line voltage and current

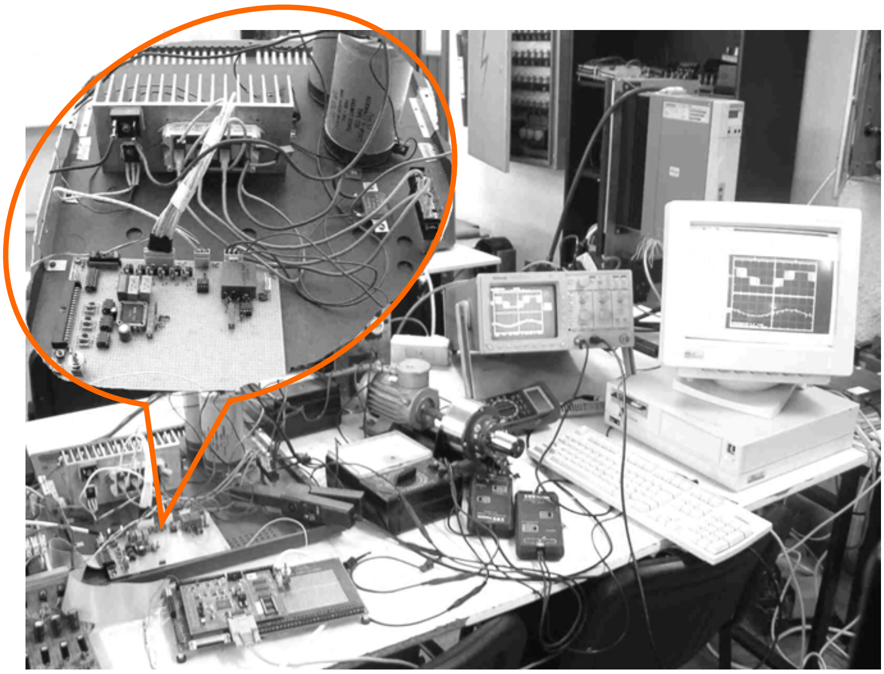

Figure 11. The arrangement with IR2233

Conclusions

This circuit offers both command and protection for three-phase inverter bridge with IGBTs, simplifying more the electrical schema.

The principal functions are present in following: over-current and UVCC protections, generate intern deadtime, simultaneously shutdown all six outputs with SD pin.

Compared to a discrete implementation of the gate drive circuit, the IR2233 solution cuts more components and PCB space.

IR2233 need a single power supply. IR2233 use the 1200V HVIC technology for the gate drive circuit of a 460VAC three-phase inverter

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