EE682
Fuel Cell Energy Processing Systems
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Prof. Ali Keyhani

Class Notes: Gate Drive Design

Fuel Cells

DC/DC Converters

Inverters

Mechatronics Laboratory

Department of Electrical Engineering

The Ohio State University

CHAPTER 7 Gate Drive Circuit Design Example

In this chapter, a gate drive circuit, interfacing the DSP and the power switches, with optical isolation, is given as an example. This example is designed for the scenario that a TI TMS320F240 DSP drives a MOSFET.

7.1 Introduction

For most power switches, microprocessor pins cannot provide enough power to drive their gates/bases to implement switching operation. Therefore, a specially designed interfacing circuit is necessary to drive the gates/bases according to the output low power signals from the microprocessor. In order to protect the microprocessor electrically from possible overvoltage or overcurrent fault, it is necessary to isolate the low power circuitry from high power one electrically while the signal is still allowed to pass through. An optical isolator (optocoupler) is an ideal device for this application.

An optocoupler consists of a primary side circuit and a secondary side circuit. The primary circuit is an LED and the secondary side is a photo transistor or light sensitive logic circuit. When the LED is lit, the secondary transistor is conducting. There is no electrical connection between the two sides. The grounds should be separate also.

To design a gate drive circuit, electrical characteristics of the involved devices (DSP, optocouplers, and power switches) need to be checked. These values will be used to determine the current limiting resistances used in both the input and output circuits of the optocouplers. The current limiting resistors will limit the both the output current of the DSP pins and the collector-emitter current of the optocoupler from exceeding the maximum.

If multiple power switches are used in the circuit, their gate drive signals cannot share the same ground because their sources (for MOSFETs) or emitters (for BJTs) are at different voltage levels according to the operating principle of the circuit. Therefore, multiple power supplies will be necessary to provide different grounds.

7.2 Gate drive design example

For an H-bridge type of inverter as shown in Figure 7-1, a TI TMS320F240 EVM is used to drive the power switches T1, T2, T3, and T4. Four PWM signals (TTL: 0~5V) are generated by the DSP PWM pins.

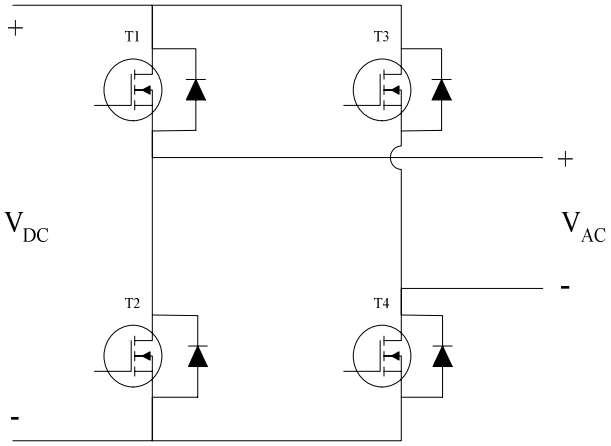

Figure 7-1 H-bridge type of inverter

If an NEC PS2501-4 optocoupler is chosen (available in the lab for free), the interface circuit can be designed as shown in Figure 7-2.

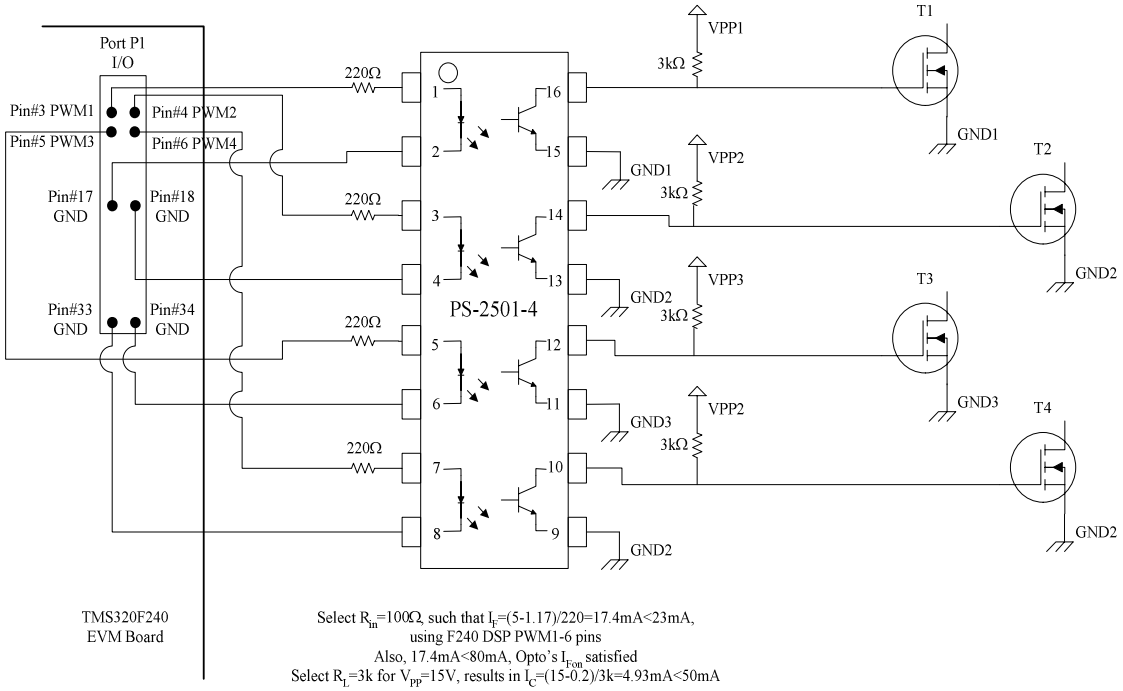

Figure 7-2 Gate drive circuit for T1 and T2

Select input resistor R_{in}=220Ω, such that the optocoupler input stage forward current I_F=(5-1.17)/220=17.4mA<23mA, where 23mA is the maximum output current capability of F240 DSP PWM1-6 pins. Also, 17.4mA<80mA, Optocoupler's I_{Fon} requirement satisfied. Select R_L=3k Ω for V_{PP}=15V, such that the collector current I_C=(15-0.2)/3k=4.93mA<50mA, where 0.2V is the collector-emitter saturation voltage and 50mA is the maximum collector current.

The optocoupler selected has a rise time t_r=3μs and a fall time t_f=5μs, which are fast enough for a 100μs PWM cycle (10kHz assumed).

From Figure 7-1, it can be observed that the sources of T2 and T4 are at the same voltage level (shorted), while the sources of T1 and T3 are at different voltage levels. Therefore, three independent grounds is needed for the secondary side of the optocoupler (GNDx, x=1, 2, 3). Three identical power supplies have been designed as shown in Figure 7-3, which output 3 channels of +14V DC voltage with separate grounds. The transformer used is 3FL20 (10V 125mA), available from Digikey.com for $8.78 each (2 is enough since each has 2 secondary coils). The rectifier bridge and electrolytic capacitor are easy to obtain.

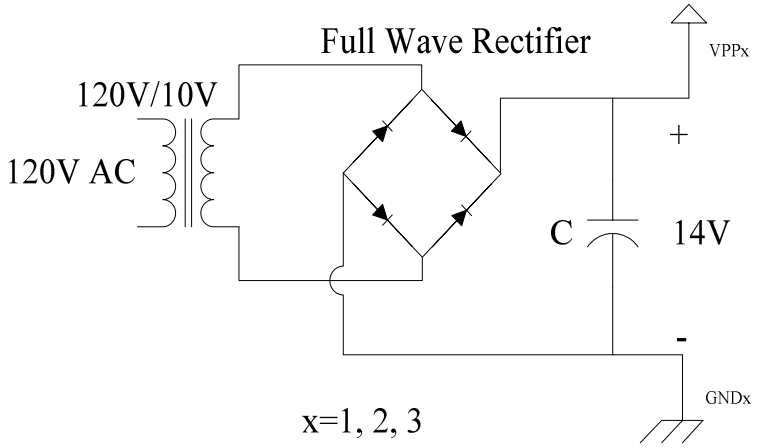

Figure 7-3 Independent +14V power supplies for the gate drive circuits

7.3 Bibliography

Datasheets: TMS320F240, PS-2501-4, 3FL20

Websites: http://www.digikey.com/ http://www.ti.com/