Industrial Stepper Motor Driver

AN43679

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Application Note Abstract

This application note demonstrates PSoC® implementation of the universal industrial stepper motor controller. Microstepping control and current limiting are also explained in detail.

Introduction

The stepper motor is a brushless electromechanical device, which converts electric pulses into discrete mechanical movements. The rotation of the stepper motor is divided into several steps, called “microsteps.” The high position precision of the stepper motor control system is achieved by using microstepping control technology. The rotor’s turning angle is proportional to the number of pulses sent into the motor. Stepper motors are widely used in low cost and open loop position control applications, such as ink jet printers, CNC machines, and volumetric pumps.

The stepper motor has the following features:

1. **Open Loop Positioning**. Precise positioning and repetition without speed and position sensors. The rotor’s tuning angle is defined by the number of pulses delivered to the motor.
2. **Holding Torque**. Holds the shaft stationary and provides full torque when stopped, if windings are powered.
3. **High Reliability**. Because the stepper motor is brushless, the life span of a stepper motor depends on the bearings.
4. **Excellent Response**. Quick start, stop, and reverse capability.

There are three basic types of stepping motors:

- Variable Reluctance Motor
- Permanent Magnet Motor
- Hybrid Motor

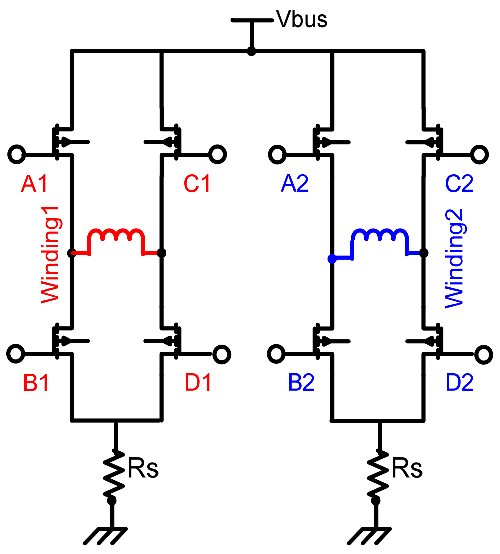
Hybrid motors are more expensive than permanent magnet motors, but they use smaller step angles, and have greater torque maximum speeds. Hybrid motors combine the best features of variable reluctance motors and permanent magnet motors.

The most popular types of motors are the unipolar and the bipolar motors. This application note explains in detail about microstepping control and the current chopper PSoC implementation of a bipolar hybrid stepper motor. This method is also applicable for permanent magnet motors.

Stepper Motor Control Method

Bipolar hybrid stepper motor driving is shown in Figure 1. Two h-bridges control the two windings.

Figure 1. Bipolar Hybrid Stepper Motor Driving



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The operational modes of the stepper motor include full step mode, half step mode, and microstep mode. The full step mode also has two driving modes: one phase on and two phase on driving modes. Each operational mode controls the motor with a different method.

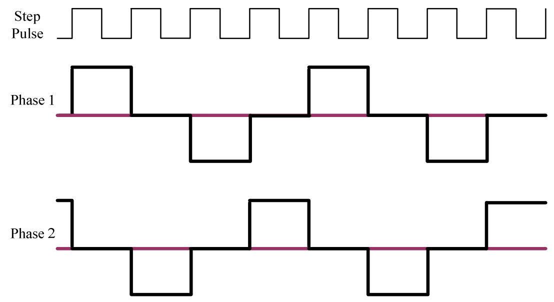
Single stepping a motor results in jerky movements of the motor, especially at lower speeds. Microstepping control achieves increased step resolution and smoother torque between steps. In addition, microstepping control has fewer noise and resonance problems. Microstepping control works on the principle of gradually transferring current from one phase to another.

The following sections describe the one phase on full step mode, half step mode, and microstep control.

Full Step (One Phase On)

The current waveform of the one phase on full step is shown in Figure 2. During every step, only one winding is powered. In the next step, the current alters to the other winding. In this mode, the torque varies in sinusoidal.

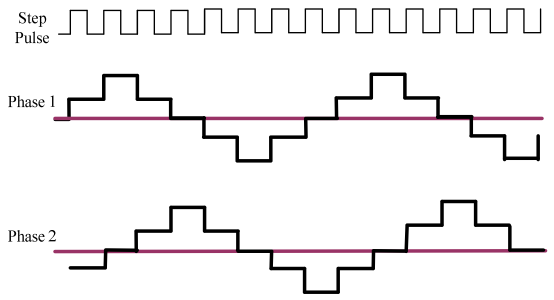
Figure 2. Full Step Current Waveform



Half Step (One and Two Phase On)

The half step mode is also called the “one and two phase on” mode. In this mode, the motor’s step is one half of a step in the full step mode. One phase is turned on during each first step and the other phase is turned on during each second step. The half step mode provides constant torque with special controls. The current waveform of the half step mode is shown in Figure 3.

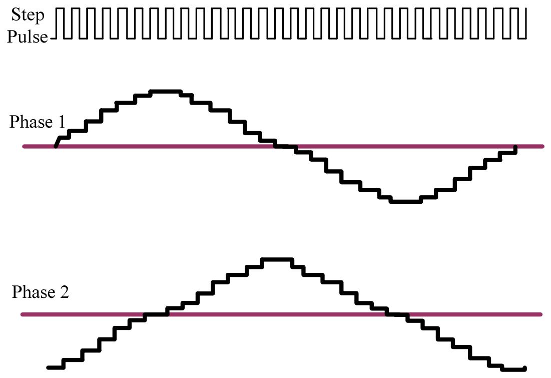
Figure 3. Half Step Current Waveform



Microstep

The waveform of eight microsteps is shown in Figure 4. With more division, the motor current is smoothly transferred from one phase to the other phase, as shown in the following figure. With sufficient division and current level, the motor phase current changes in a sinusoidal fashion. Thus, the torque of the motor keeps a constant value.

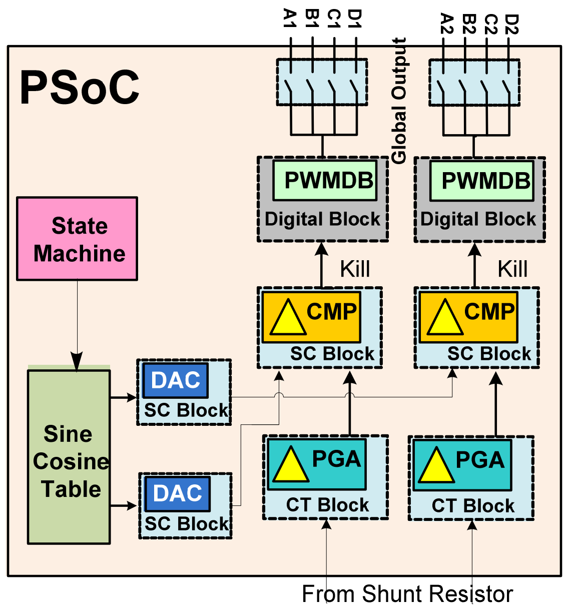
Figure 4. Eight Microsteps Current Waveform



PSoC-Based Implementation

The control diagram of the PSoC-based stepper motor driver is shown in Figure 5.

Figure 5. Control Diagram



This solution has lower system costs compared with the existing products because of PSoC’s internal flexible digital and analog user modules. As seen in Figure 5, the PSoC-based stepper motor driver includes four main parts: state machine, sin or cosine voltage generator, kill signal generator, and PWM driving signals.

When booting up, the system detects board configurations such as rotation direction, current level, and stepping pace. The system provides four current options and six step paces. Then the system stands by and waits for incoming step pulses. If no pulse comes within a predefined time interval, the system enters the half current mode. The current in the half current mode is half of the current in the normal operation. This saves power consumption and also generates holding torques to keep the motor stable.

A built-in sin or cosine table is stored in PSoC's internal Flash. A Digital-to-Analog Converter (DAC) is used to set the winding current in microstep mode. Precise positions are achieved in microstep mode. The voltage output of the DAC is the winding current reference and is fed into a comparator input. Another comparator input is the sampled winding current. The winding current is sampled by a shunt resistor, which is placed between the system ground and the winding as shown in Figure 1 on page 1. The voltage on the shunt resistor is proportional to the current flowing through the windings.

The comparator output is high if the sampled winding current is higher than the DAC output reference current, otherwise the comparator output is low. The comparator output is the kill signal routed into the PWM Dead Band generator (PWMDB). An active high kill signal drags the PWMDB low. PWMDB output is routed to pins through the Global Output Bus.

The PSoC device internals are shown in the Appendix. The user modules used in the application follow:

1. Two PWMDBs
2. Two SC Blocks for DAC
3. Two SC Blocks for Comparator
4. Two PGA for On-Chip Adjustable Current Level
5. One Timer Block for Half Current Mode Detection
6. Two DigBufs for Internal PWMDB Output Signal Routing

Stepper Motor Driver

The driver board with motor is shown in Appendix 1 on page 4. It is an industrial controller with configurable current, rotation direction, and microsteps. It also has a step pulse input interface.

The features of the driver follow:

- Bipolar Stepper Motor
- PWM Current Regulator
- Pulse Command Receiver Interface
- Individual Power Switches
- Two H-Bridge Circuits
- Automatic Half Current at Still
- Microstep Configurable
- Selectable Dynamic Motor Phase Current Volume
- Optional Rotation Clockwise or Counterclockwise

There are eight switches (SW1 to SW8) that are used to select rotate direction, current level, and the number of microsteps.

Table 1 lists the current configuration. The current selection depends on the load.

Table 1. Dynamic Current Configuration

SW7	SW8	Peak Current
On	On	0.6A
Off	On	1.0A
On	Off	1.6A
Off	Off	3.0A

Table 2 lists the selection of the number of microsteps.

Table 2. Microstep Configuration

SW1	SW2	SW3	Microstep	Step/Revolution
On	On	Off	Fullstep	200
On	Off	On	Halfstep	400
Off	Off	On	4	800
Off	On	Off	8	1600
On	Off	Off	16	3200
Off	Off	Off	32	6400

SW4-On selects rotating clockwise, or counterclockwise.

The step command input, +5V pulse, is fed into the stepper motor driver. The higher the frequency of the pulse command, the faster the motor spins. Thus, both speed and the position of the stepper motor may be precisely adjusted by an external controller at every moment.

The Software

The flowchart of the software is shown in Appendix 3 on page 6.

In the main loop, PSoC monitors the change of dynamic current settings and acts accordingly.

When an external pulse command comes in, an IO interrupt is triggered. As a result, *MstepCnt*, which is used to counter microstep numbers, increases by *MStep*. The lookup sin/cos table faction uses *MStepCnt* as a pointer to generate the sin or cosine current reference value.

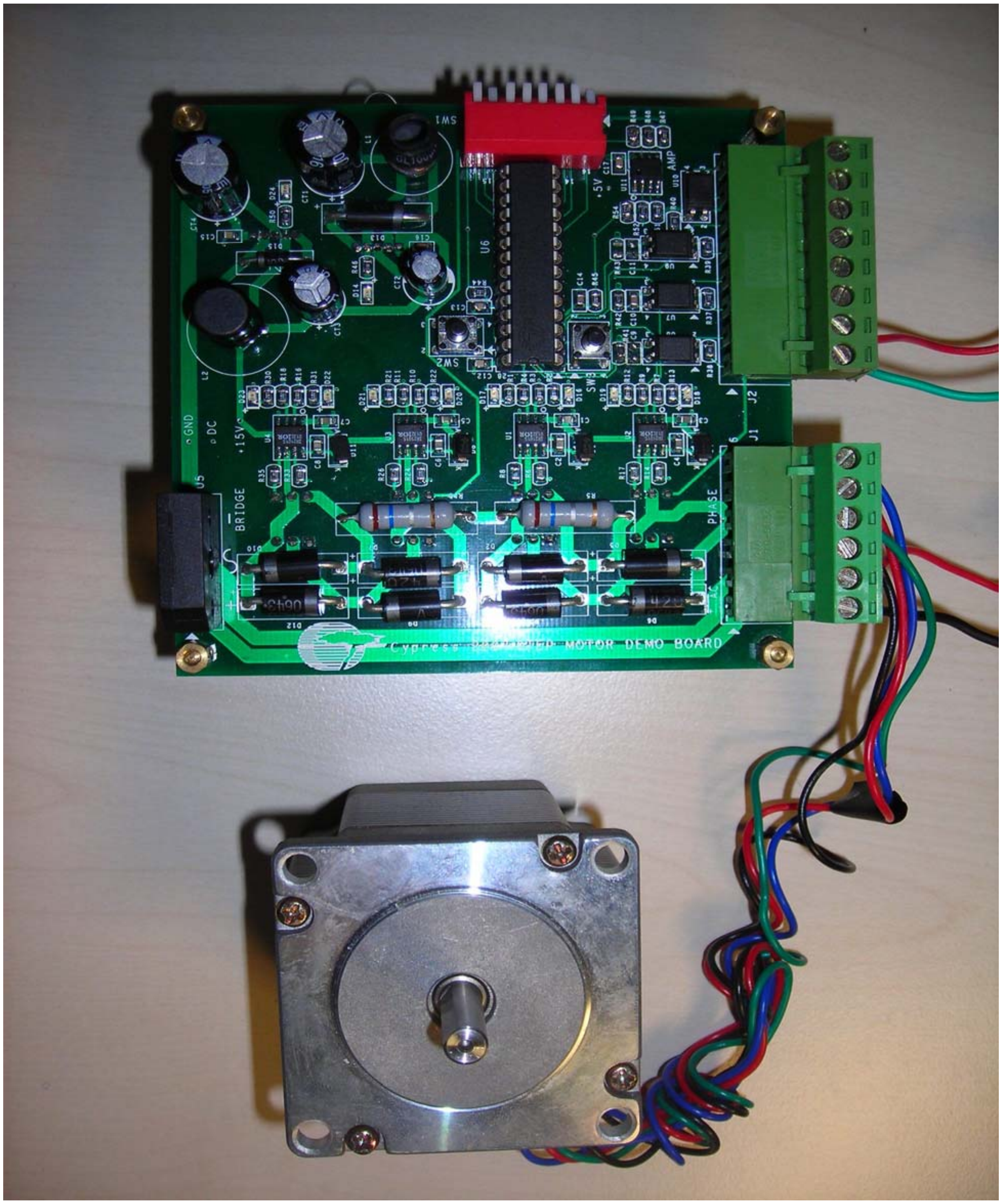
When *MStepCnt* loops to zero, the software enters the step switching code. In this code, the patterns of the power switches are rearranged according to the internal state machine. The direction of the stepper motor may be easily changed by inverting the step loop sequence.

Summary

This application note describes stepper motor control based on PSoC. With the assistance of a PSoC device, the stepper motor driver implements microstepping control, and allows the user to easily configure parameters.

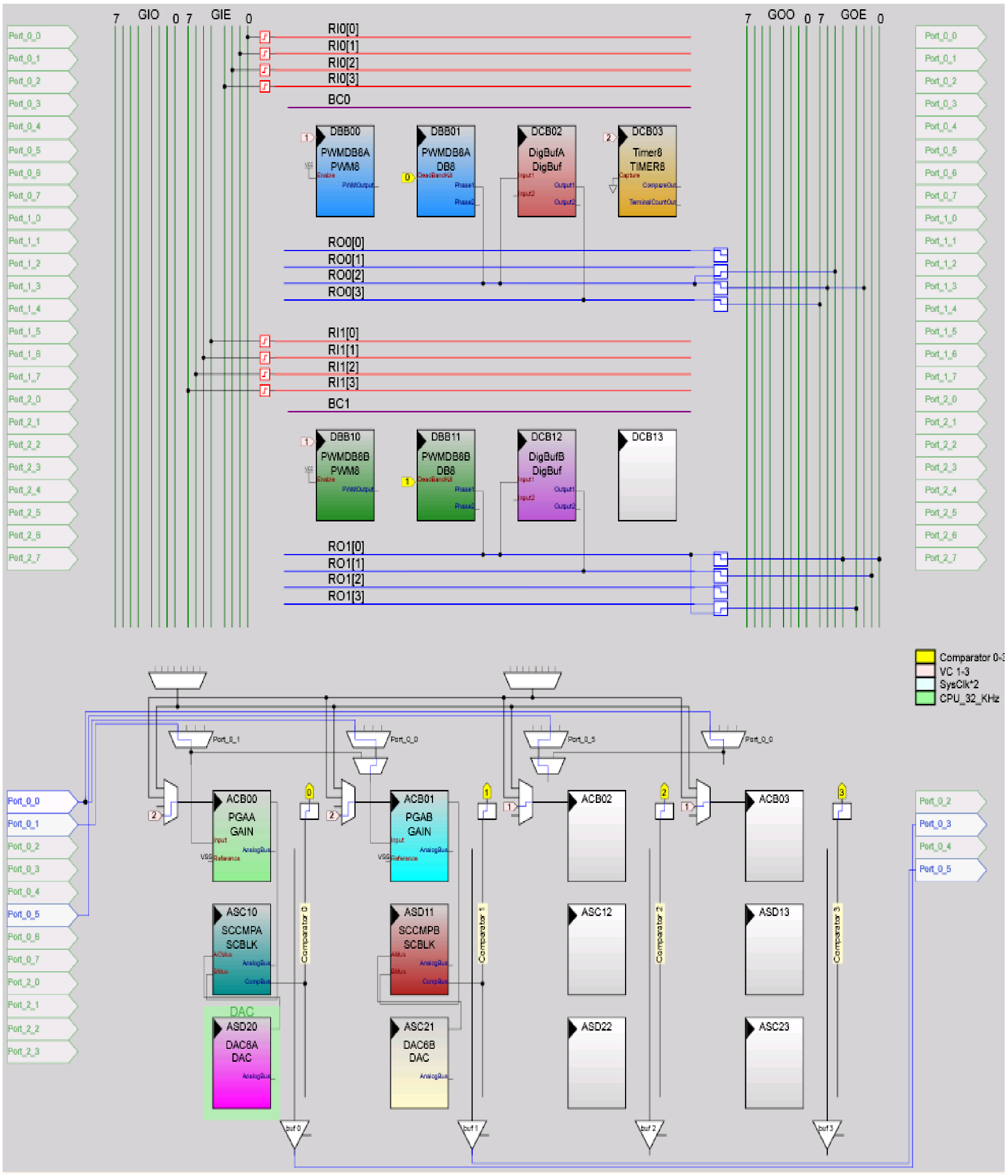
Appendix 1

Figure 6. Stepper Motor Driver Board



Appendix 2

Figure 7. User Module Placement in PSoC Designer



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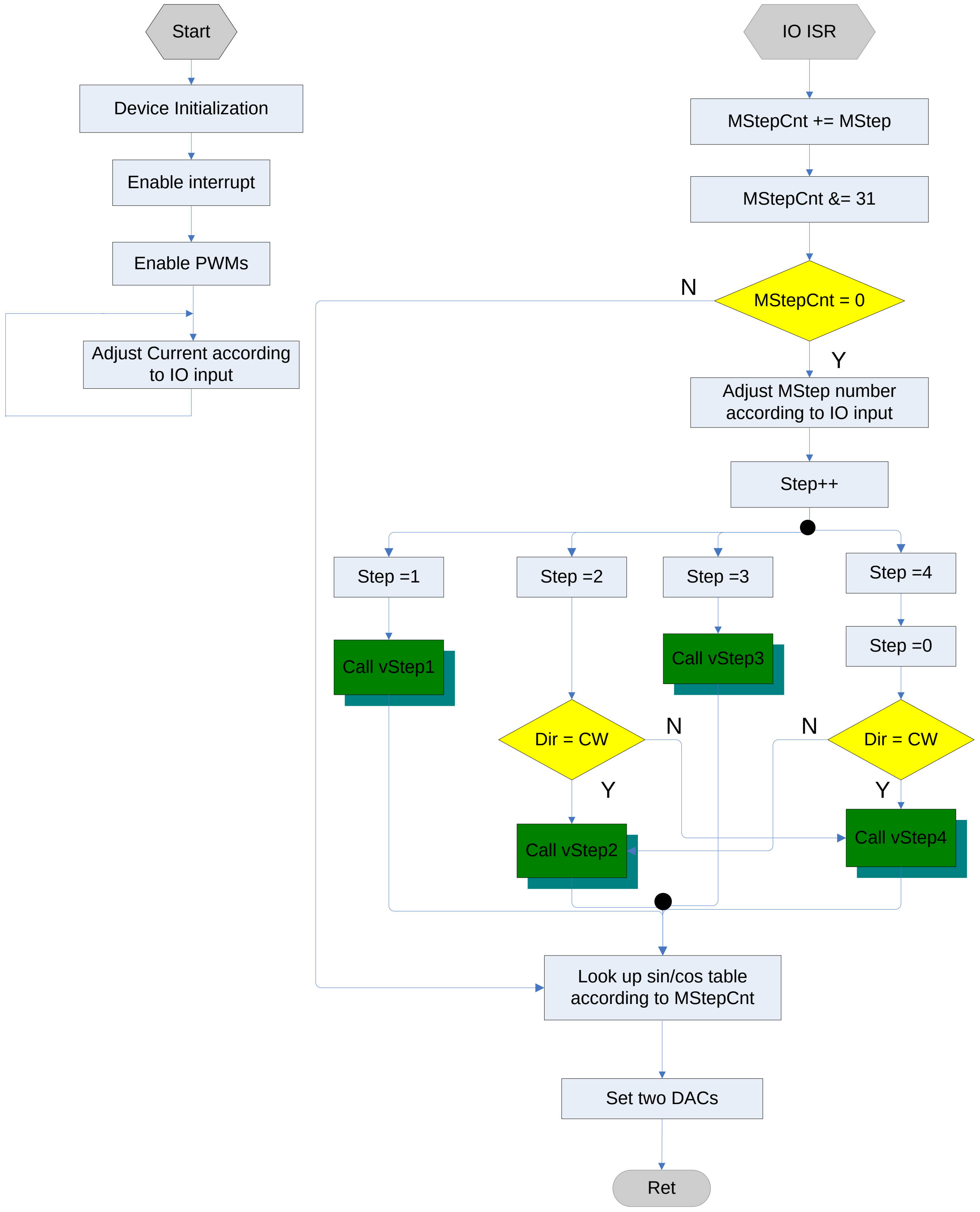
Appendix 3

Figure 8. Software Flowchart



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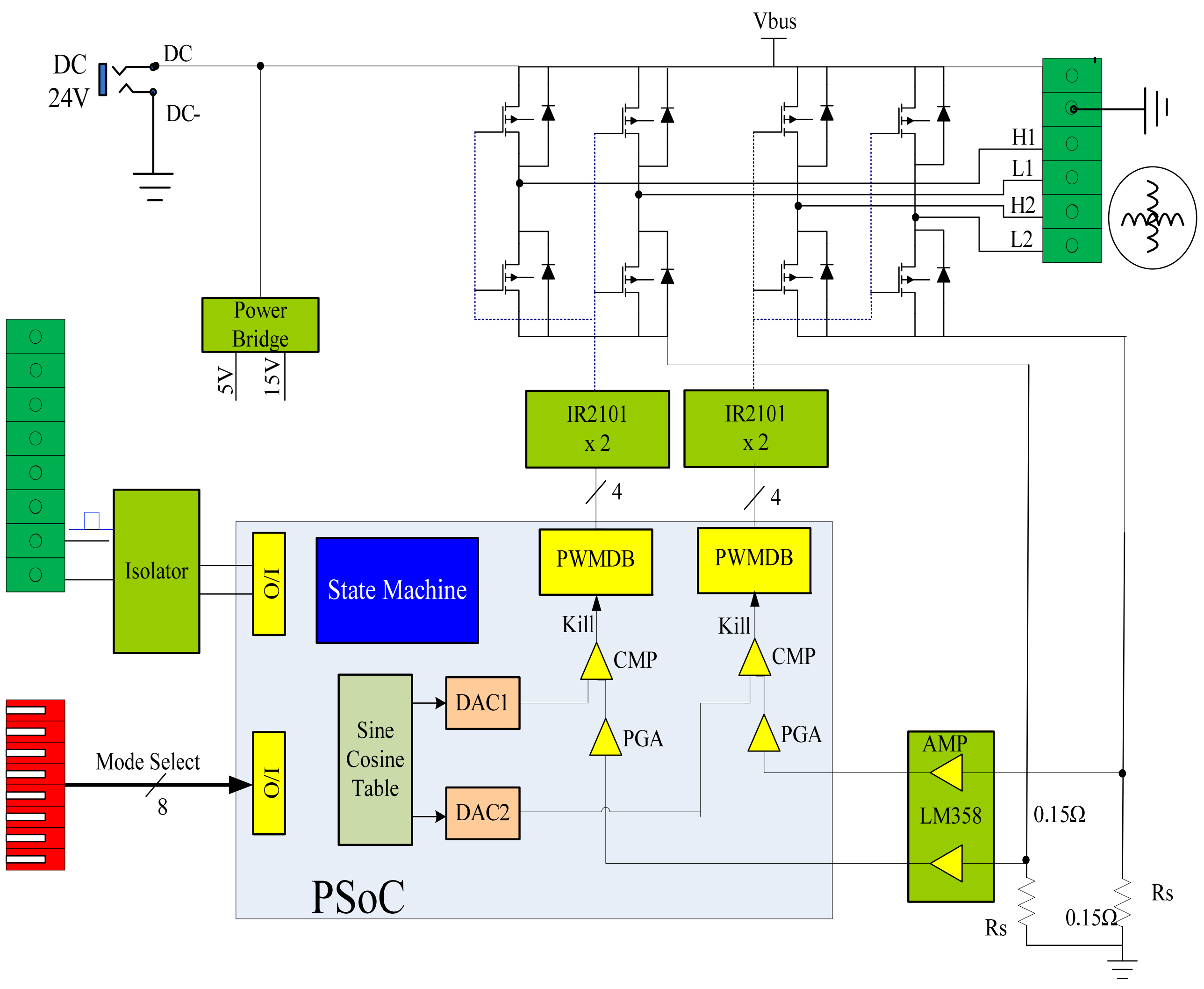
Appendix 4

Figure 9. Board Control Diagram



Appendix 5

Figure10. Schematic (Control Circuit)

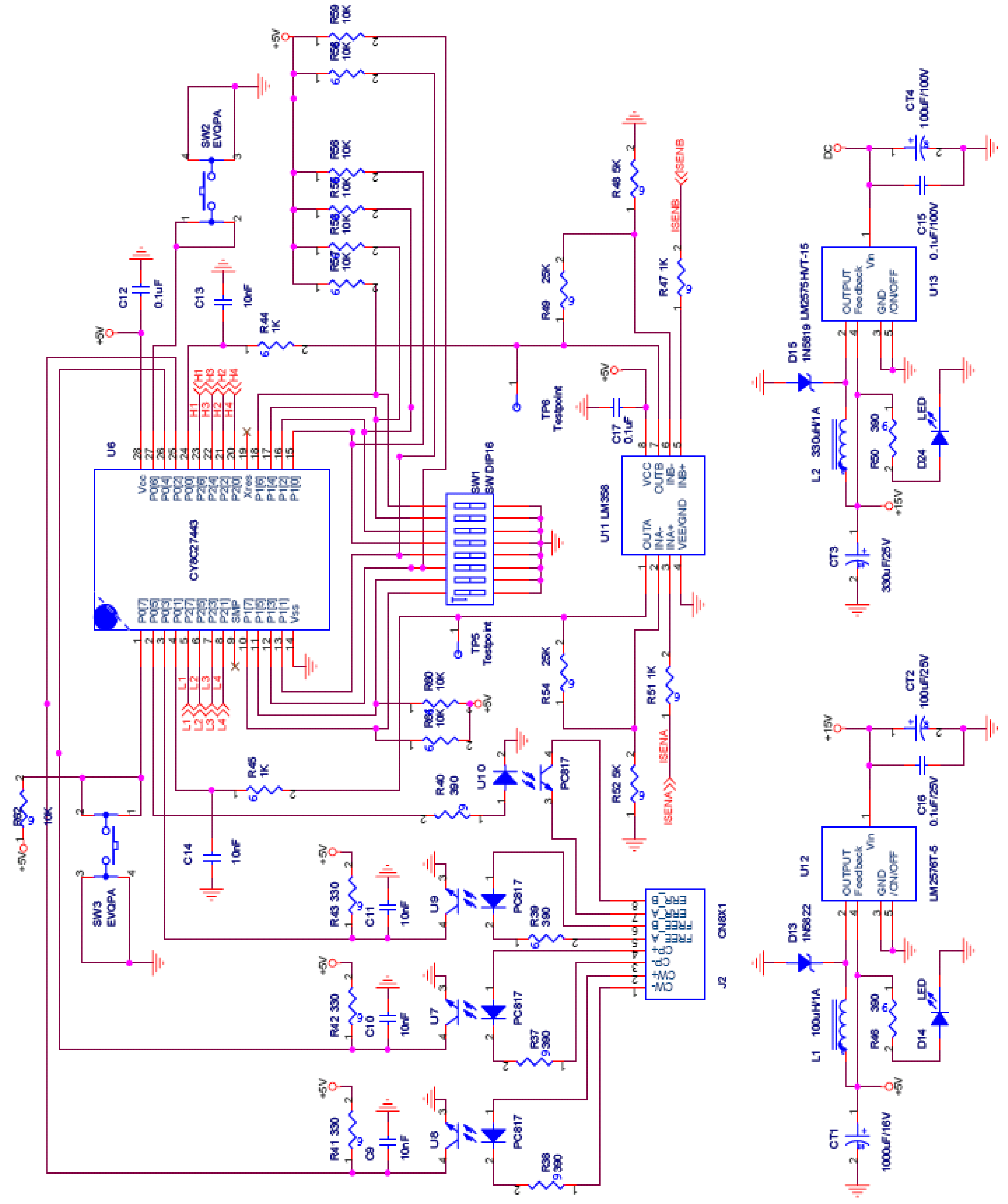


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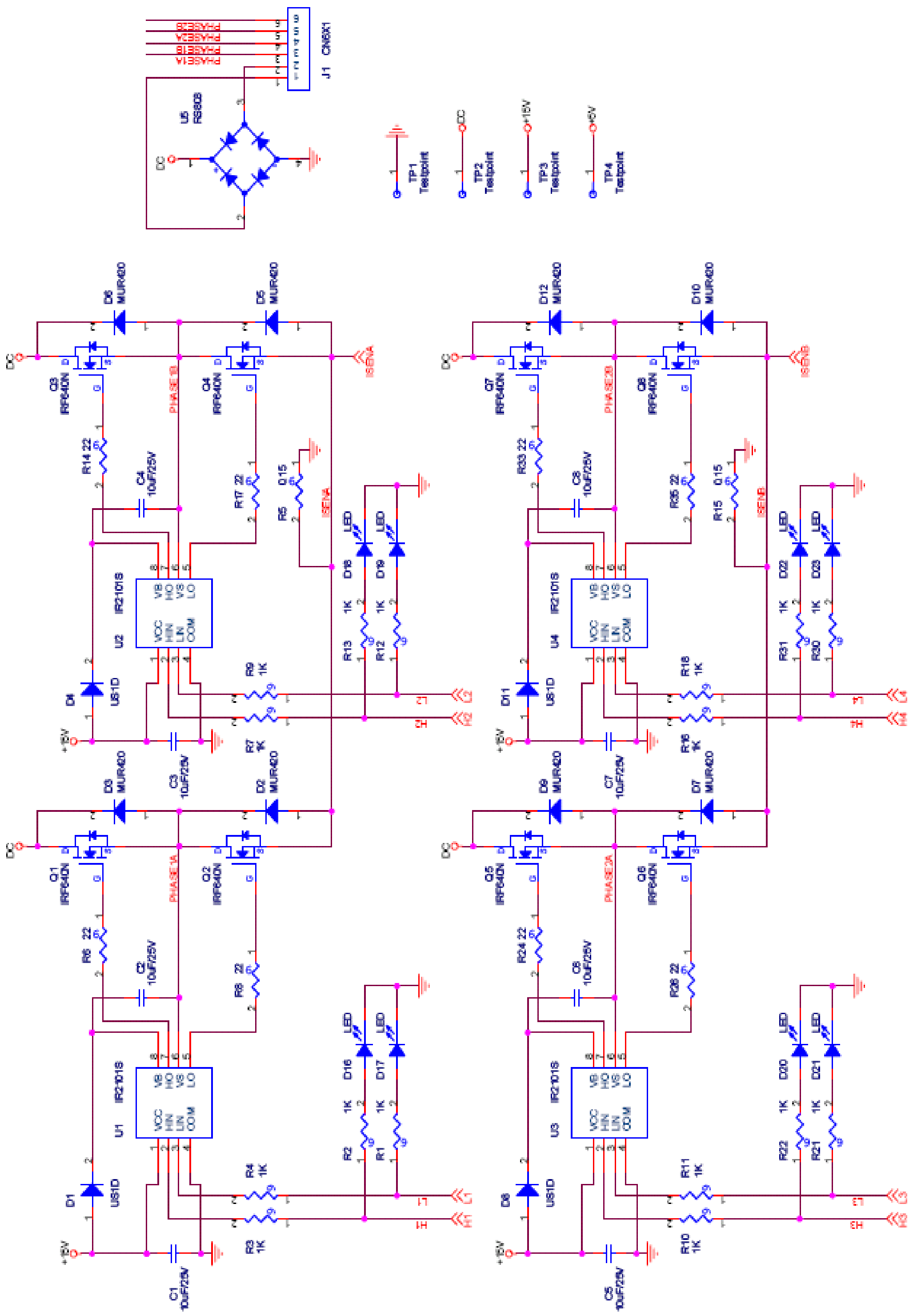
Figure 11. Schematic (Drive Circuit)



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