Registration number: TI2866

Eligible Part: EKK-LM3S9B96

Project Synopsis

The challenge of this project was to design a 48VDC to 30VAC 7.5 KW inverter to power a three phase alternating current induction motor, which will be the main drive system of a motorbike which was converted from gas to electricity. The motor has a rating of 30Volts AC, 215 Amps and 7500 Watts.

The control system isa 48VDC to 30VAC inverter. The system consists of a **Stellaris Luminary LM3S9B96** microcontroller, an Intersil HIP4086 three phase driver chip, and 12170V/260A n-channel MOSFETsmounted on a custom aluminum heat sink. Optical isolation protects the control system from the high power system.

The control system will be implemented usingoptical isolation on a Honda CBR1000F Hurricane motorbike. The bike will be capable of 0-120Hz drive frequency which is approximately 0-100+MPH.

The **EKK-LM3S9B96** microcontroller is the heart of the three phase control system. The microcontroller is responsible for taking an **A**nalog to **D**igital **C**onversion of an analog voltage signal outputted from an electronic throttle which determines the motor drive frequency of the motorbike.

Based on the value of the **ADC** a **P**ulse **W**idth **M**odulated signal is generated, the width of this pulse is determined based on the values of a **S**ine **L**ookup **T**able. The table contains 256 12bit entries detailing one complete cycle of a sine wave. As a pointer to the **SLT** is incremented by the returned value of the **ADC** the value being loaded into the **PWM** generator is the value that the pointer is pointing at in the **SLT**. The more table entries the pointer skips in one **PWM** cycle the greater the output frequency becomes.

The **PWM** frequency being used is 20 KHz this was chosen so that any switching noise is above the human hearing threshold. Since the value being loaded into the PWM generator every 50us is a different value we end up with a variable duty cycle **PWM**which has a constant switching frequency of 20 KHz. This varying duty cycle creates a sinusoidal average voltage.

The other two phases of the AC signal are generated by using an offset value from the first AC signals pointer address, so that there is never any shifting between the phases and that they remain 120 degrees apart for all switching cycles.

The microcontroller also utilizes a control signal to enable and disable the gate signals sent to the N-Channel MOSFETs. This control signal is based off of the position of the throttle so at rest the MOSFET’s are disabled and motor will not be able to move the bike.

After the signals are outputted from the microcontroller they are fed directly into a HCPL-7710 opto-coupler which has a built in amplifier, this opto-coupler is CMOS compliant and due to its internal amplifier system it does a level conversion from the output of the microcontroller which is a 0-3V signal to a 0-5V.

The 0-5V signal is sent through a series resistor of 600 ohms in order to limit the output current of the opto-coupler to less than 9 mA, this is to prevent any damage occurring to the opto-coupler. The resistor is connected to the input of a HIP4086 three phase FET driver.

The HIP4086 FET driver has several features, soft start, hardware controlled dead-time, under voltage protection, isolated drive circuitry for powering high side n-channel MOSFETs using a bootstrap supply internal to the IC, and has the ability to drive 6 MOSFETs in a three phase half-h bridge configuration.

The HIP4086 FET driver has four signals sent to it three separate gate signals which are used to generate the three phase AC signals, and one control signal which Enables/!Disables the output of the FET driver. The FET driver is responsible for subtracting time from the high side switch's gate signal in order to implement dead-time in between the turn on of the high side switch and the turn on of a low side switch. This is done in order to prevent a shoot through situation where there is a direct short between power and ground.

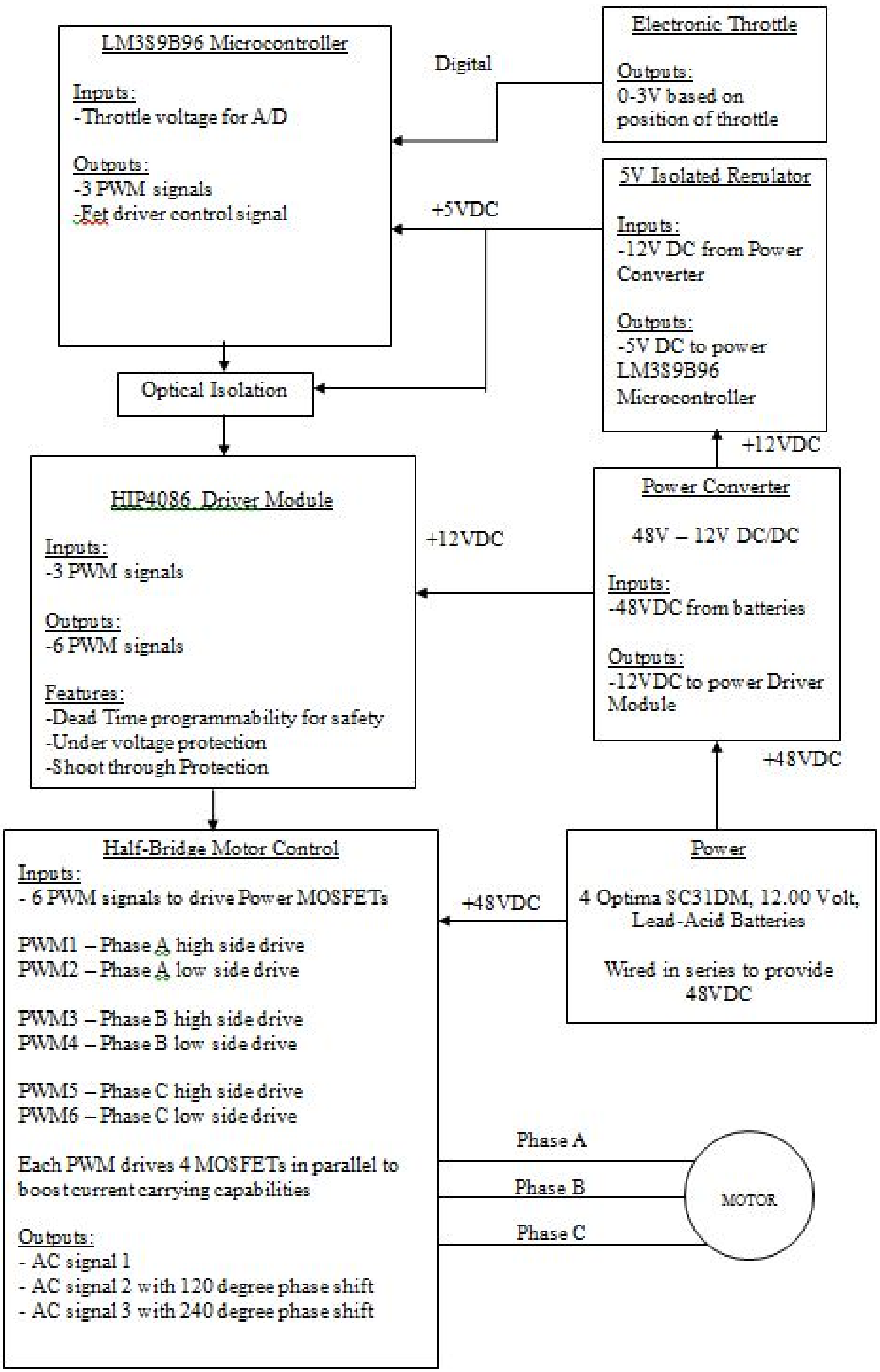
These gate signals are sent to 12 n-channel Enhancement MOSFETs; the MOSFETs are configured in a half-h bridge with 2 MOSFETs in parallel for both high and low side. Using the MOSFETs in parallel was done in order to have sufficient head room above the maximum rated current for the three phase AC induction motor. There are three half-h bridges in this inverter design in order to make up the three phase signal.

The MOSFET's used in this design are IXYS IXFK260N17T n-channel Enhancement MOSFETs rated at 260A and 170V each capable of dissipating 1670W per MOSFET.

These MOSFETs are directly mounted on custom aluminum bus bars and phase bars. The bus bars are made out of 6061 T6 aircraft grade aluminum. The bus bars connected to the batteries on the bike have a continuous current rating of 1200 Amps, and the phase bars which have a direct connection to each phase of the three phase motor has a continuous current rating of 600 Amps. The bus and phase bar system was custom made in house and the high current ratings are due to a 200% safety margin used in the design process since the motor being used is an untested prototype.

The motor was a custom built at a local motor shop it is designed to have a nominal output power of 7500 Watts at 30 Volts AC with a current draw of 215 Amps. After initial testing it was found that the motor requires 30-35 volts of magnetizing current to generate a rotating magnetic field.

Control System Block Diagram



Project Photo

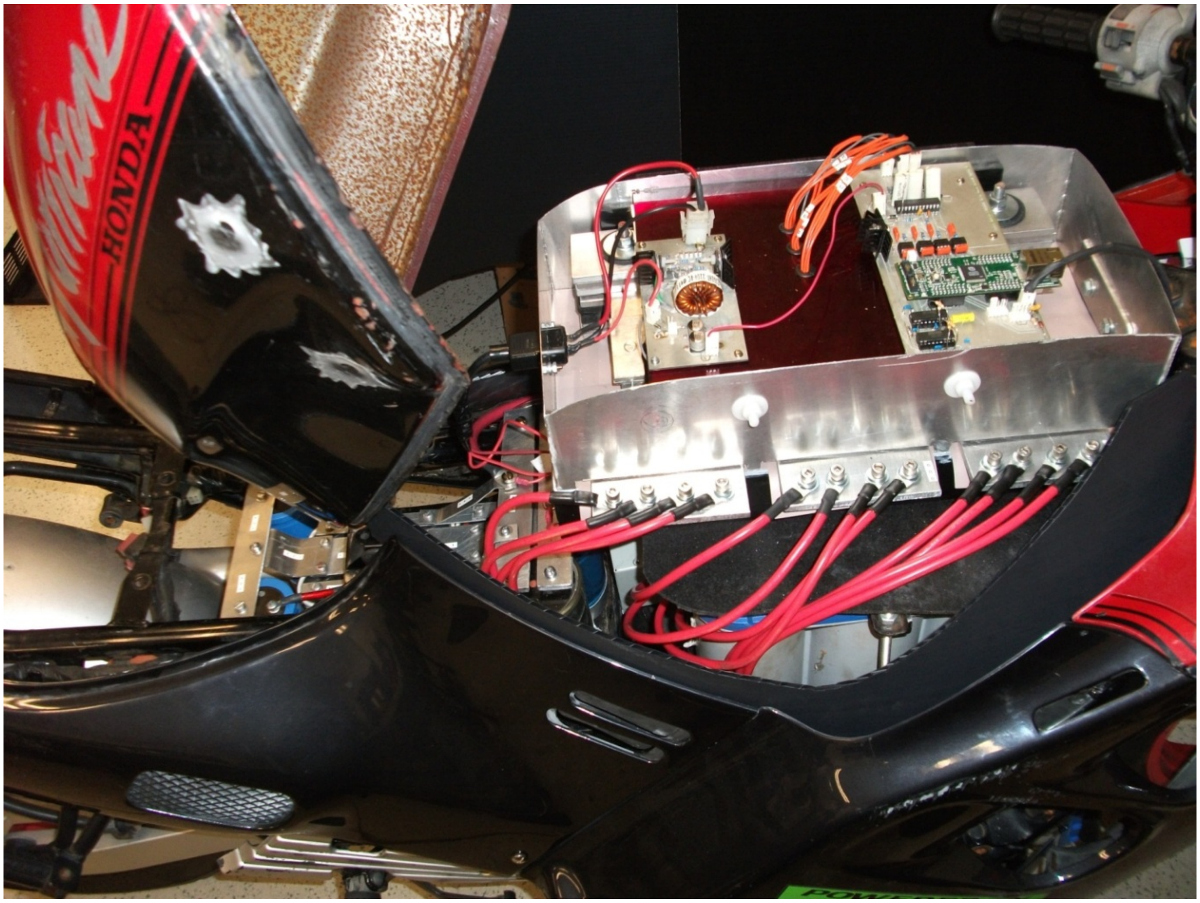


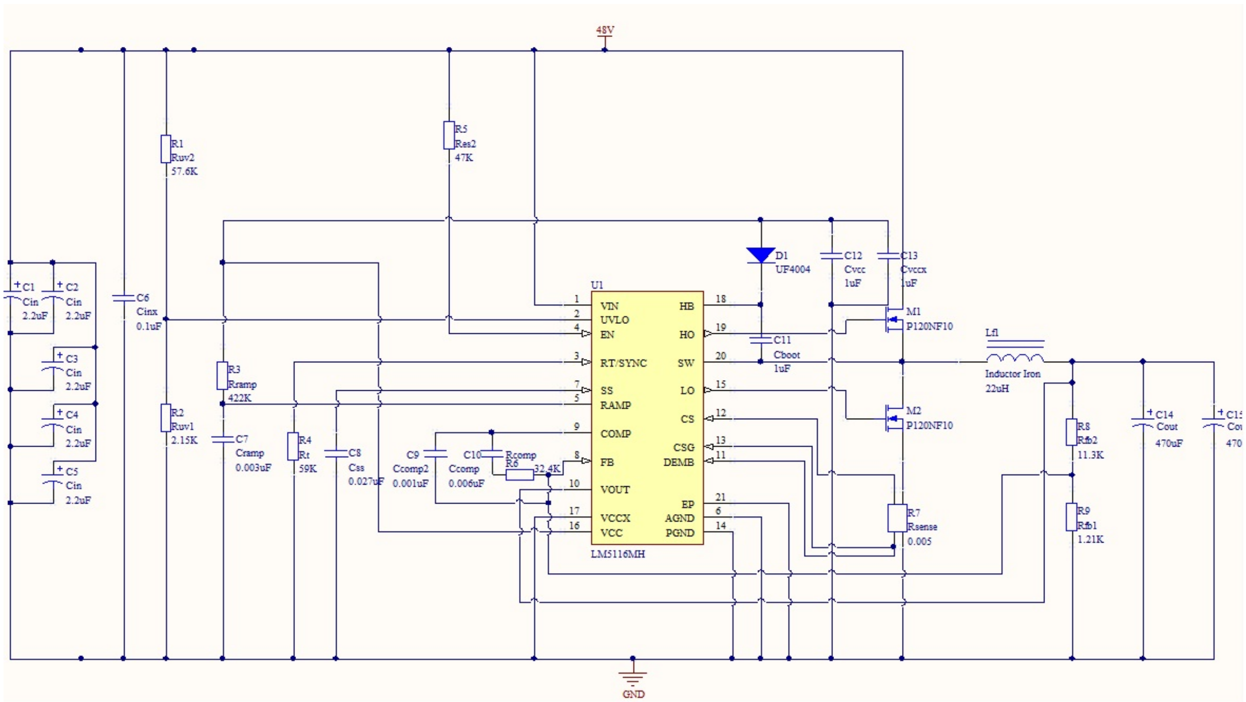
Figure 1: 48VDC to 30VAC three phase inverter

Code Example

/*this section of code takes the ADC conversion value and puts it in ADC_Code variable.
The variable is then divided by 2 to divide the output frequency in half. This variable has 0x00091 subtracted from it to compensate for the idle output voltage of the throttle. The throttle output 0.850V - 2.90V with a throttle reference voltage of 3.6V. The min ADC code output is 0x0122 and the maximum ADC_code is 0x03FE (before dividing by 2) The min ADC code output is 0x0091 and the max ADC code is 0x01FF (after dividing by 2). */

```
//get the latest A/D conversion value
ADC_Code = usValueAvg;
//usValueAvg = 0;
//ADC_Code = 0x03FF;

//divided the output frequency by half
ADC_Code = ADC_Code>> 1;

//subtract off the idle voltage value from the ADC convertion
if(ADC_Code>= 0x0091)
{
        Freq = ADC_Code - 0x0091;
}
else
{
        Freq = 0;
}
//hysteresis implemented in order to prevent faulty gate toggling
//test if the throttle is idle
if(Freq< 0x0004)
{
        //if frequency is less than 1Hz disablethe gate drives
        GPIOPinWrite(GPIO_PORTD_BASE, GPIO_PIN_6,0x40);
}
if(Freq>= 0x0008)
{
        //otherwise set the pin low and drive the gates
        GPIOPinWrite(GPIO_PORTD_BASE, GPIO_PIN_6,0x00);
}




//for 30VAC motor
//test if within the 0-60Hz range
if(Freq<= 0x009F)
{
        //save a copy for V/F testing
        VF_test = Freq;
```

```
}
else
{
	VF_test = 0x009F;		//used to reduce total % of pwm duty cycle
}

//set the index to be based on the previous index value
Freq = (Freq + lastFreq);

//preserves the index number from the previous cycle
lastFreq = Freq;

//offset from address location zero by 120 degrees
Freq2 =(Freq+0x5555);

//offset phase2 by 240 degrees
Freq3 =(Freq+0xAAAA);

//shifting off bits outside the table range
Freq = (Freq>> 8);
Freq2 = (Freq2 >> 8);
Freq3 = (Freq3 >> 8);

//get the new table index value
Phase1PWM = *(phase1Ptr + Freq);
Phase2PWM = *(phase1Ptr + Freq2);
Phase3PWM = *(phase1Ptr + Freq3);
```


48V
R1
Ruv2
57.6K
R5
Res2
47K
C1
Cin
2.2uF
C2
Cin
2.2uF
C6
Cinx
0.1uF
C3
Cin
2.2uF
C4
Cin
2.2uF
C5
Cin
2.2uF
R2
Ruv1
2.15K
R3
Rramp
422K
C7
Cramp
0.003uF
R4
Rt
59K
C8
Css
0.027uF
C9
Ccomp2
0.001uF
C10
Ccomp
0.006uF
Rcomp
R6
32.4K
U1
VIN
UVLO
EN
RT/SYNC
SS
RAMP
COMP
FB
VOUT
VCCX
VCC
HB
HO
SW
LO
CS
CSG
DEMB
EP
AGND
PGND
LM5116MH
D1
UF4004
C11
Cboot
1uF
C12
Cvcc
1uF
C13
Cvccx
1uF
M1
P120NF10
M2
P120NF10
Lf1
Inductor Iron
22uH
R7
Rsense
0.005
R8
Rfb2
11.3K
R9
Rfb1
1.21K
C14
Cout
470uF
GND