3-PHASE POWER INVERTER

Guide to operate the 3-phase inverter experimental setup

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1 FEATURES

- The 3-phase 30A@450V power inverter for academic/research purposes;
- This inverter has built-in measurements of AC currents, AC voltages and DC bus voltage;
- The inverter is based on infineon IPM IKCM30F60GA module (a low-cost module, with integrated drivers);
- The control board is based on XMC4500 Relax (lite) kit, a well-known board in UP Laboratory of Power Electronics;

2 SCHEMATIC

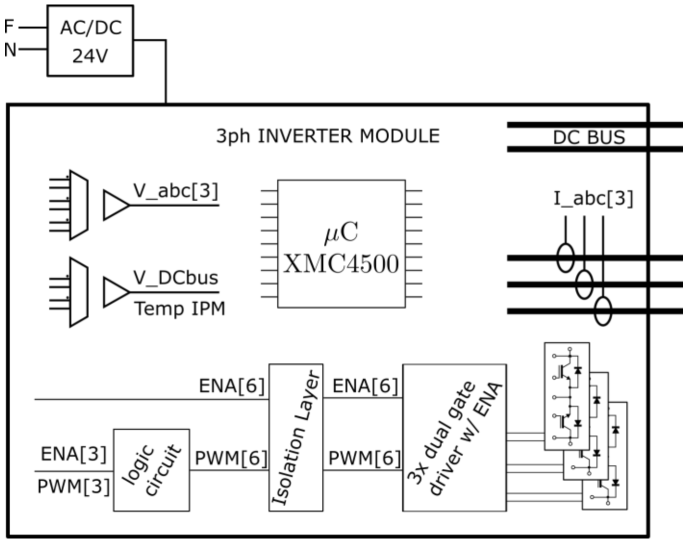

Figure 1 - general schematic.

3 PWM GENERATION WAVEFORMS

The PWM generation implemented in this power inverter module uses the following logic circuit:

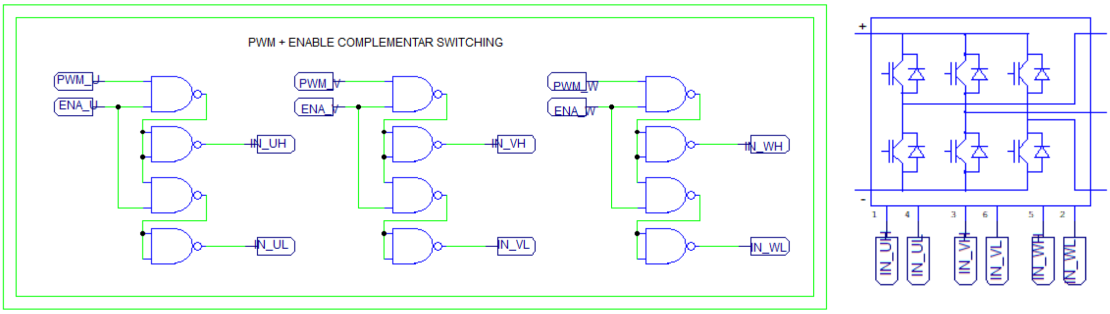

Figure 2 – Detail of logic circuit for PWM generation.

This arrangement allows the generation of two complementary PWM for each inverter arm. In addition, there is an enable signal for each inverter arm.

These signals pass through an isolation layer, and later though three dual gate drivers, with enable, for each transistor, following:

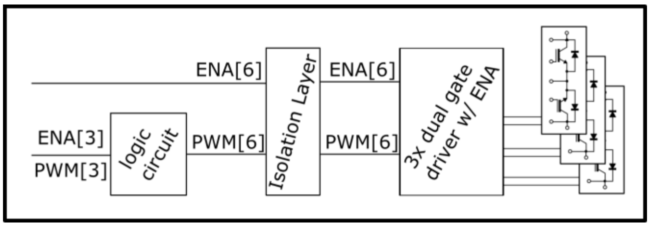

Figure 3 - General PWM generation.

On the XMC4500 side, the PWM pins are the following:

Functional pin	XMC4500 pin	description
PWM U	P0.4	Pwm signal
PWM V	P0.6	Pwm signal
PWM W	P0.5	Pwm signal
ENA U	P2.6	Enable arm U
ENA V	P5.2	Enable arm V
ENA W	P5.0	Enable arm W
iso_ENA_UH	P0.2	Enable arm U high side IGBT
iso_ENA_UL	P3.2	Enable arm U low side IGBT
iso_ENA_VH	P0.11	Enable arm V high side IGBT
iso_ENA_VL	P3.1	Enable arm V low side IGBT
iso_ENA_WH	P3.3	Enable arm W high side IGBT
iso_ENA_WL	P3.0	Enable arm W low side IGBT

4 ACQUISITION OF ELECTRIC WAVEFORMS

This setup has built-in measurements of electric waveforms, specifically three currents (for each of the phases), the DC voltage and three AC isolated voltage measurements.

4.1 CURRENT MEASUREMENTS (THREE INTERNAL MEASUREMENTS)

The current measurement is performed with an isolated hall effect based current sensor, specifically the ACS713ELCTR-20A-T. The maximum value for the AC current sensor is +/- 20A peak.

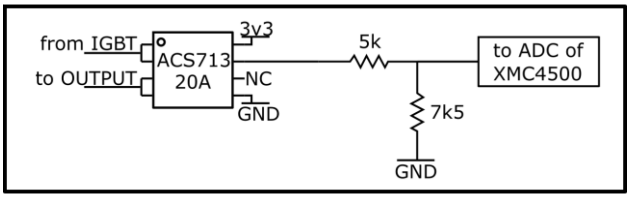

Figure 4 - Schematic for internal current measurment. NOTE1: the resistors can be removed to reach the maximum scale of the ADCs; NOTE2: for the external measurement, the same circuit is employed, without resistors.

x20A PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1]; V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		0	–	20	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	178	185	190	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 2 kHz external filter, 185 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = 10 nF, 2 kHz bandwidth	–	21	–	mV
Zero Current Output Slope	$\Delta V_{OUT(Q)}$	T_A = –40°C to 25°C	–	0.08	–	mV/°C
		T_A = 25°C to 150°C	–	0.16	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.035	–	mV/A/°C
		T_A = 25°C to 150°C	–	0.019	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P = 20 A, I_P applied for 5 ms; T_A = 25°C	–	±1.5	–	%

[1]Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.
[2]Percentage of I_P, with I_P = 20 A. Output filtered.

Figure 5 - Detail of the datasheet

In the provided code, the acquisition is performed at the beginning of the 10 kHz interruption, in the "Update_PWM(void)" function:

```
/// ADC acquisition - AC Currents
I_abc_adc[0]=ADC_MEASUREMENT_ADV_GetResult(&ADC_MEASUREMENT_2_V2_2);
I_abc_adc[1]=ADC_MEASUREMENT_ADV_GetResult(&ADC_MEASUREMENT_1_V1_4);
I_abc_adc[2]=ADC_MEASUREMENT_ADV_GetResult(&ADC_MEASUREMENT_1_V1_3);

I_abc[0]=(I_abc_adc[0]- (1800.0f + 74.8f)) * 0.022222222f;
I_abc[1]=(I_abc_adc[1]- (1800.0f + 77.0f)) * 0.022179506f;
I_abc[2]=(I_abc_adc[2]- (1800.0f + 70.8f)) * 0.021897810f;
```

Due to the precision of the resistors in the resistor divider, an offset and gain error occurs. A practical calibration of each sensor is recommended, with the calibration procedures presented in section 6.4.

4.2 DC_BUS Voltage Measurement

The DC bus voltage measurement is performed with an isolation amplifier, namely the AMC1311, as illustrated in the following figure:

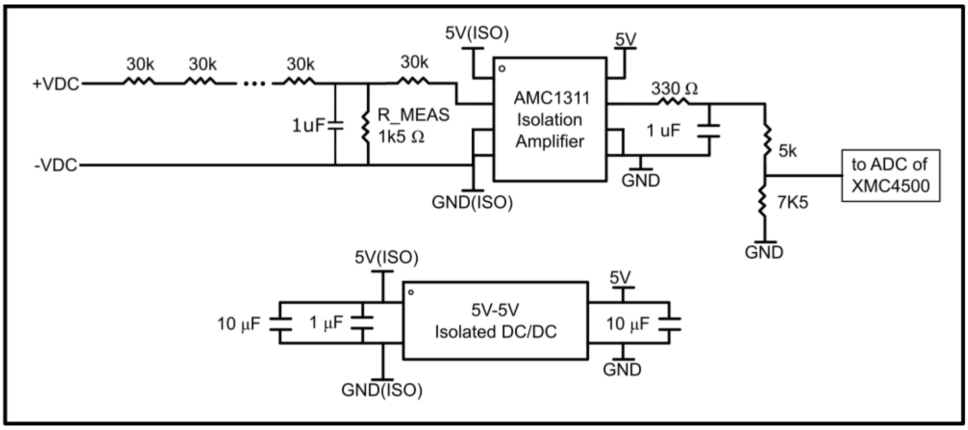

Figure 6 - Schematic for DC voltage measurement

Similarly, in the provided code, the acquisition is performed at the beginning of the 10 kHz interruption, in the “Update_PWM(void)” function:

```
/// ADC acquisition – DC_BUS Voltage
V_DC_adc = ADC_MEASUREMENT_ADV_GetResult(&ADC_MEASUREMENT_1_V1_2);
V_DC = (V_DC_adc-(1800.0f + 22.4f)) * -0.58f;
```

Due to the precision of the resistors, an offset and gain error occurs. A practical calibration of each sensor is recommended, with the calibration procedures presented in section 6.4.

4.3 AC Voltage Measurements (Three Measurements)

Similarly to the DC Bus Voltage measurement, AC voltage measurement is performed with an isolation amplifier, as illustrated in the following figure:

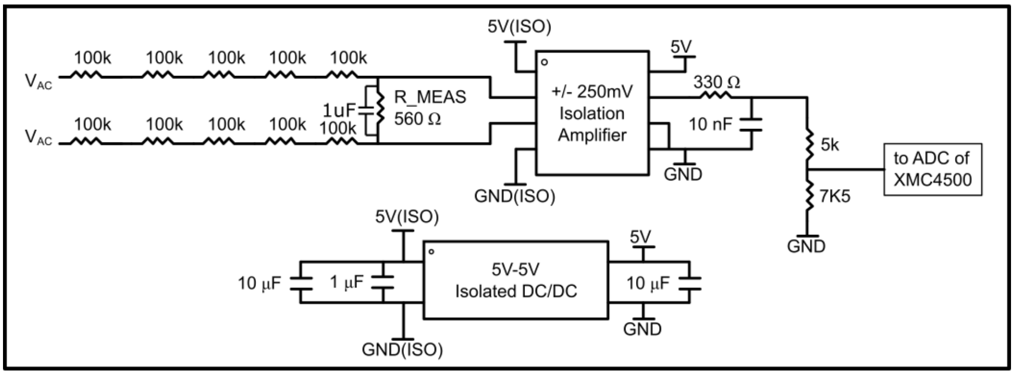

Figure 7 - Schematic of AC voltage measurement

In the provided code, the acquisition is performed at the beginning of the 10 kHz interruption, in the “Update_PWM(void)” function:

```
/// ADC acquisition - AC Voltages
V_abc_adc[0]=ADC_MEASUREMENT_ADV_GetResult(&ADC_MEASUREMENT_1_V1_1);
V_abc_adc[1]=ADC_MEASUREMENT_ADV_GetResult(&ADC_MEASUREMENT_2_V2_1);
V_abc_adc[2]=ADC_MEASUREMENT_ADV_GetResult(&ADC_MEASUREMENT_2_V2_3);

V_abc[0]=(V_abc_adc[0]- (1800.0f + 23.92f)) * 0.720f;
V_abc[1]=(V_abc_adc[1]- (1800.0f + 16.50f))  * 0.720f;
V_abc[2]=(V_abc_adc[2]- (1800.0f + 2.930f)) * 0.720f;
```

Due to the precision of the resistors in the resistor divider, an offset and gain error occurs. A practical calibration of each sensor is recommended, with the calibration procedures presented in section 6.4.

4.4 TEMPERATURE MEASUREMENT

Based on the built-in thermistor of IKCM30F60GA IGBT module, the temperature is acquired, with the following code:

```
float conv_temperature = ADC_MEASUREMENT_ADV_GetResult(&ADC_MEASUREMENT_3_V3_1);
float conv_temp_C =(conv_temperature*conv_temperature*-0.00016973) +  //x^2
                         (conv_temperature*0.69969095) +  //x^1
                       -653.10731030;  //x^0
conv_temp_C += 7.0f;  //offset compensation (junction temperature)
```

This is performed with the isolation amplifier AMC1311.

4.5 PINOUT

Functional pin	XMC4500 pin	description
Vabc_0	P14.1	Voltage AC
Vabc_1	P14.3	Voltage AC
Vabc_2	P14.5	Voltage AC
Vdc_bus	P14.7	Voltage DC bus
Temp_IPM	P14.13	IPM temperature (termistor)
Iabc_1	P14.8	Current at phase Iu
Iabc_2	P14.2	Current at phase Iv
Iabc_3	P14.0	Current at phase Iw
Irst_0 (Flat cable 2)	P15.2	Current at grid side phase R
Irst_1 (Flat cable 3)	P14.14	Current at grid side phase S
Irst_2 (Flat cable 4)	P14.12	Current at grid side phase T
EXTRA (Flat cable 5)	P14.6	NOT USED
EXTRA (Flat cable 5)	P14.4	NOT USED

5 VERSION CONTROL

V1.0 – preliminary – v.morais@fe.up.pt
V1.1 – added PWM generation details, ADC details and minor updates in the How to use section – v.morais@fe.up.pt
V1.2 – Major revision for REV 4.0 – vmorais@fe.up.pt