Freescale Semiconductor
Application Note

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DSC MC56F84xxx in the motor control application

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1 Introduction

3-phase high voltage or low voltage motors are used in large number of applications. The various types of motors require a various control algorithms, which are often very complex. Freescale offers a family of Digital Signal Controllers (DSC) MC56F84xxx dedicated for control of complex motor control algorithms. One of the latest DSC is 100MHz 32-bit MC56F84789. For the successful control of the application the DSC peripherals must be utilized and properly connected to the power hardware control and feedback signals.

2 Key peripherals dedicated for motor control applications

The two eFlexPWM modules PWMA and PWMB for the control signal generation

- up to 12 output PWM channels
- 16-bit resolution for edge, center aligned or asymmetrical PWM
- Independent control of both edges of each PWM output
- Independently programmable PWM output polarity
- Independent top and bottom deadtime insertion

- Each complementary pair can operate with its own frequency and deadtime values
- The PWMA supports NanoEdge placement with 312 ps high resolution

Two independent 12-bit high speed cyclic ADC for the analog signal measurements:

- 8-channel external input each
- 300 ns conversion speed
- Each ADC has ability to scan and store up to 8 conversion results

- 1 x 24-channel 16-bit SAR ADC
- 1 x 24-channel 16-bit SAR ADC
- One quadrature decoder
- Two periodic interval timers
- Two programmable delay blocks
- One 12-bit DAC
- Four high speed comparators with 6-bit DACs for comparator reference
- Dual inter-module crossbar switch enabling user configuration of data path between internal modules and between internal modules and GPIO pins.

  This DSC with large FLASH (up to 256 KB) and RAM (up to 32 KB) memories is running at 100 MHz. It is powered from +3.3 V power supply and it has the 5 V tolerant I/O pins.

  DSC is able to control two 3-phase motors together with one common power factor control (PFC) stage simultaneously. The suggested connections for the one or two 3-phase motors optionally with PFC stage are proposed below.

3 Power Stage Structures

Let's start with the design of the key parts of typical power stage.

- Motor inverter
- Interleaved PFC
- Current and voltage feedback measurement.

3.1 Motor Inverter

The basic hardware connection for one motor is shown in Figure 1.

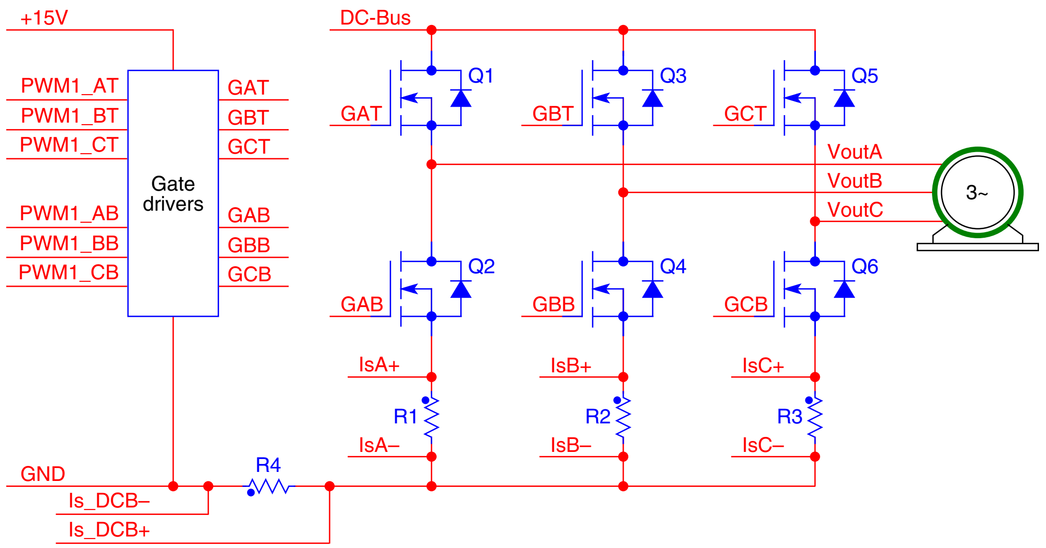

Figure 1. 3-Phase Motor Connection

The Figure 1 shows the basic internal connection of the 3-phase power module typical for motor control application. The input gate driver block receives the control signals from the control DSC and generates the control signals for the IGBTs or MOSFETs. This stage is usually able to accept the control signals of the 3.3 V to 5 V level. The block of the gate drivers is powered from the +12 V to +15 V power supply (Vdd). The 3-phase bridge of the power MOSFETs or IGBTs is powered from the high voltage DC-Bus line (100V DC to 400V DC).

3.2 Interleaved PFC Stage

The PFC stage is commonly used to improve the efficiency of the power consuming from the power line. The power factor is decreased by the current spikes when the DC-Bus capacitors are charged from the standard diode bridge rectifier. The PFC stage maintains the mains current nearly sine shape, thus the power factor is close to 1.

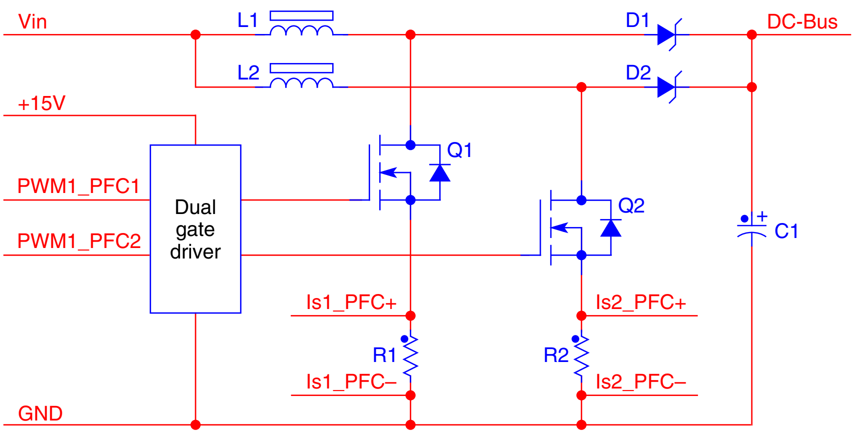

Figure 2. Interleaved PFC Stage

The basic structure of the interleaved PFC stage is shown in Figure 2. The input to the PFC stage is the Vin voltage. It is the power line AC voltage rectified by the diode bridge. Vin is the pulsating DC voltage. This voltage is measured by the control DSC. The DSC generates the PWM control signals for the power MOSFETs in order to consume sine shape current from the power line. The high frequency switching currents are sensed by the current sense resistors R1 and R2, then amplified and measured by the ADC module of the DSC. The output DC-Bus voltage is usually stabilized at level about 380V DC. The DC-Bus voltage provides power for the motor inverter.

3.3 Current and Voltage Measurement

The current and voltage measurement is the key factor for the proper control of the motor. The currents of the each phase are sensed by the power current sense resistors. The voltage on the each sensing resistor is amplified by the measurement amplifier. The structure of this current sense amplifier is shown in Figure 3. The amplification factor is suggested to be lower than 10.

Voltage levels are typically measured by the simple voltage divider, which scales the high voltage to proper level acceptable by the processor. The voltage dividers for phase B and C are like for the phase A in Figure 3.

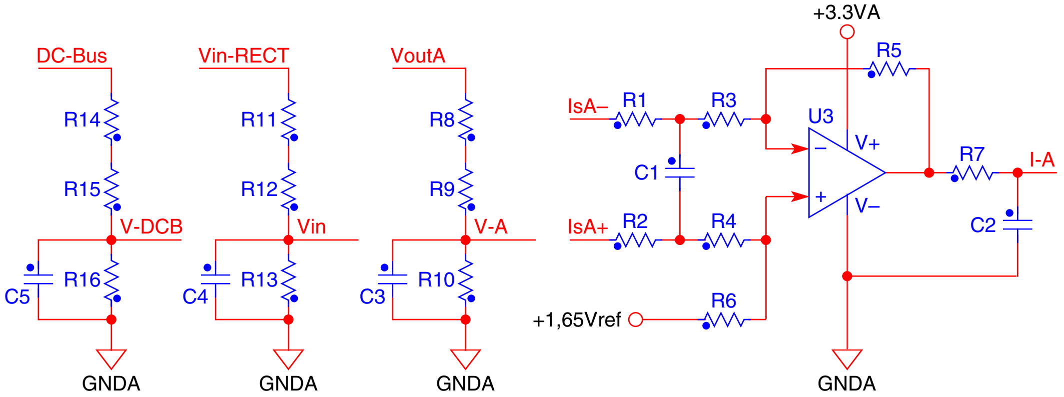

Figure 3. Voltage dividers and current sense amplifier for phase A

The input components R1, R2 and C1 form the noise filter. The voltage reference +1.65 V enables the measurement of currents of the both polarities. For the DC-Bus current measurement this reference voltage is equal to zero. Then the only positive current polarity is measured. At the output of this amplifier is the simply low pass filter which improves the measurement accuracy. The output of this filter is connected to the ADC input of the DSC.

4 Hardware Connections

This section describes the DSC MC56F84xxx connections for the various configurations of the motor control application.

The field oriented control (FOC) is mostly used for control of the 3-phase generic motors. The control algorithm requires the simultaneous (at the same time) measurement of the currents of the two phases of the 3-phase system. This task can be accomplished by the two ADC modules in the DSC. The measured values are processed by the DSC software algorithm. The control algorithm then generates the 3-phase PWM signals for the power stage control. The basic control algorithm is shown in Figure 4.

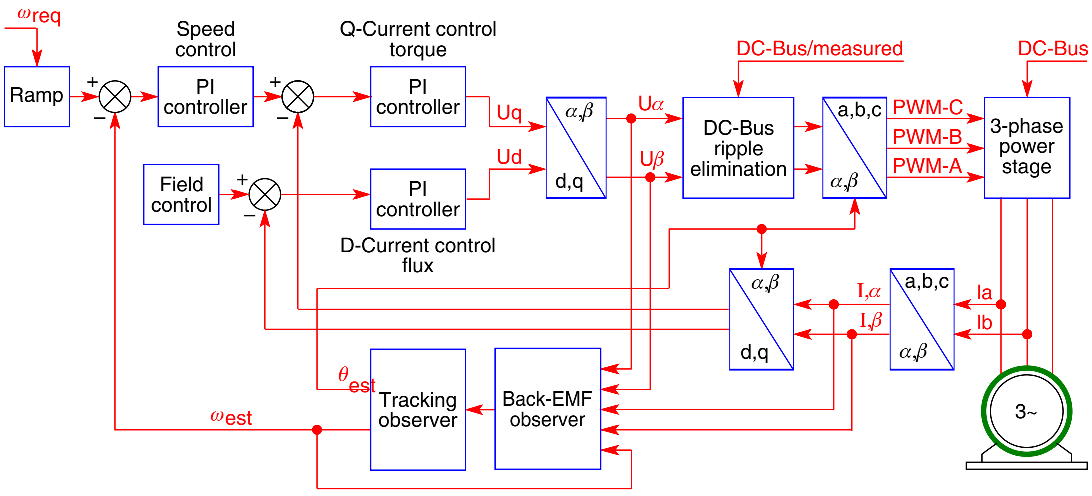

Figure 4. Basic Control Block for PMSM

The control DSC MC56F84xxx is able to manage all these tasks for simultaneous control of the two motors with PFC stage together. The following sections describe the suggested hardware connection for one and two motor control with PFC stage.

4.1 Power Supply and DSC's JTAG Interface connection

The DSC's power supply pins and JTAG connection for DSC is shown in Figure 5. Please meet the basic power supply rules for the layout design – place the blocking capacitors as close to DSC's power supply pins as possible.

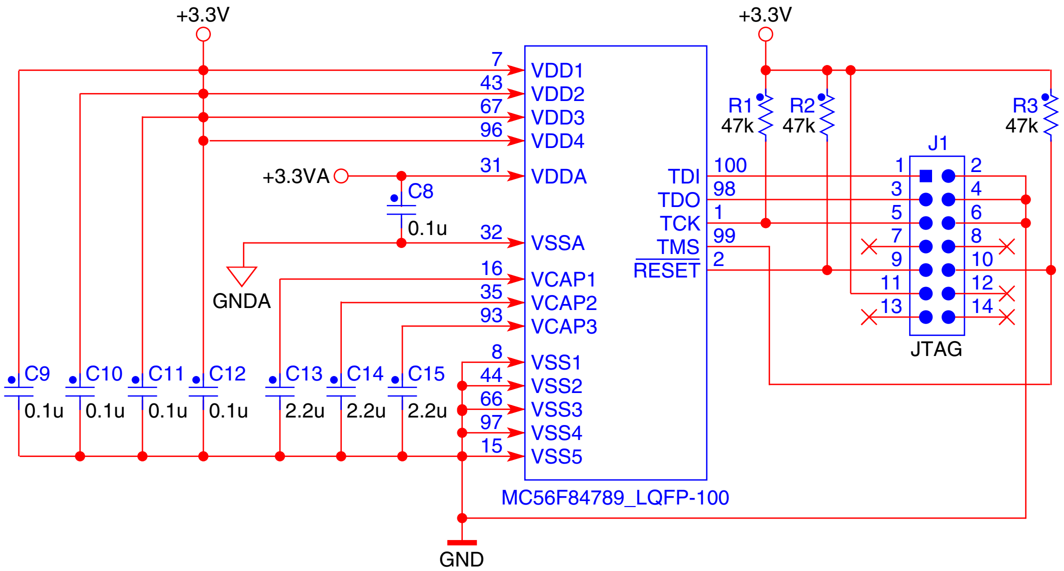

Figure 5. DSC's power supply pins and JTAG connection.

4.2 One 3-Phase Motor without PFC Stage

This is the simplest motor control application usually used for the low power (< 100W) application. The power limitation is due to valid regulation – the only low power motor control applications can be used without PFC stage.

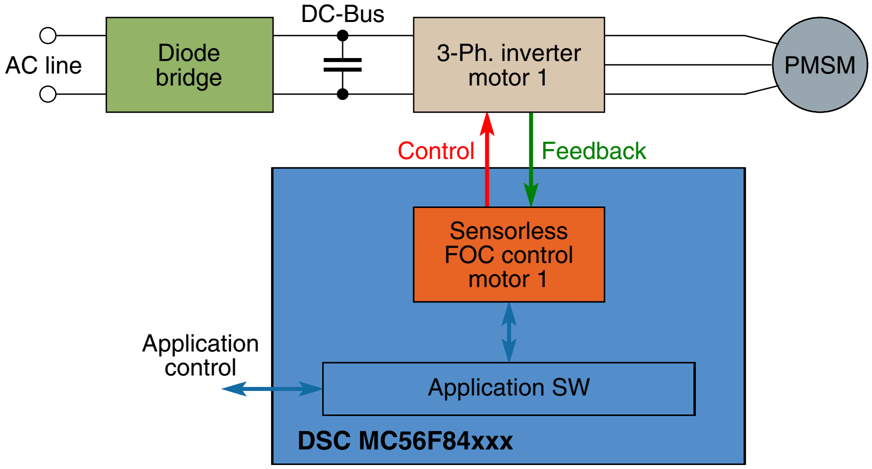

Figure 6. One Motor Control without PFC Stage

The block schematic of the power circuit for the one motor control without PFC stage is shown in Figure 6. The power supply schematic is shown in Figure 7.

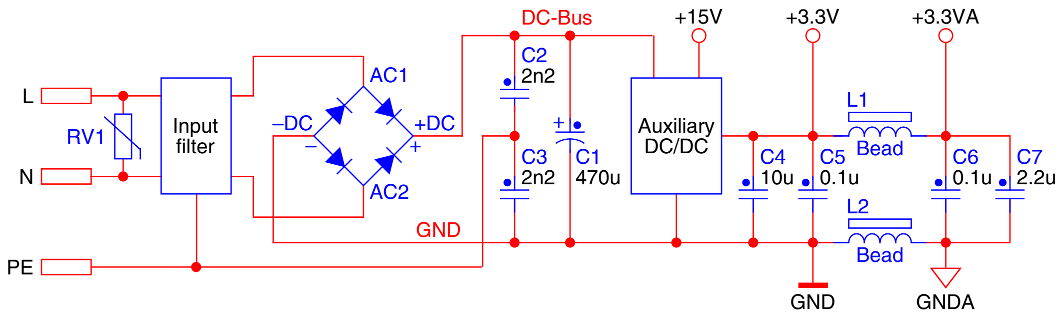

Figure 7. Power supply without PFC

The measured currents and voltages are scaled by the voltage dividers and measurement amplifiers and connected to the control DSC as in Figure 8.

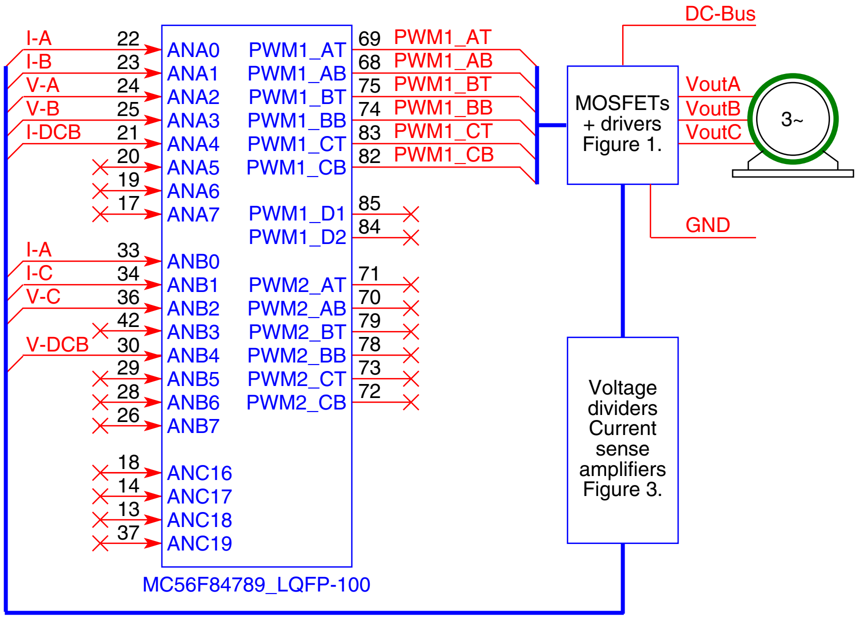

Figure 8. Measurement and control signals for one 3-phase motor without PFC

4.3 One 3-Phase Motor with PFC Stage

This configuration is often used for the high power motor control application. For higher power the interleaved PFC stage is used.

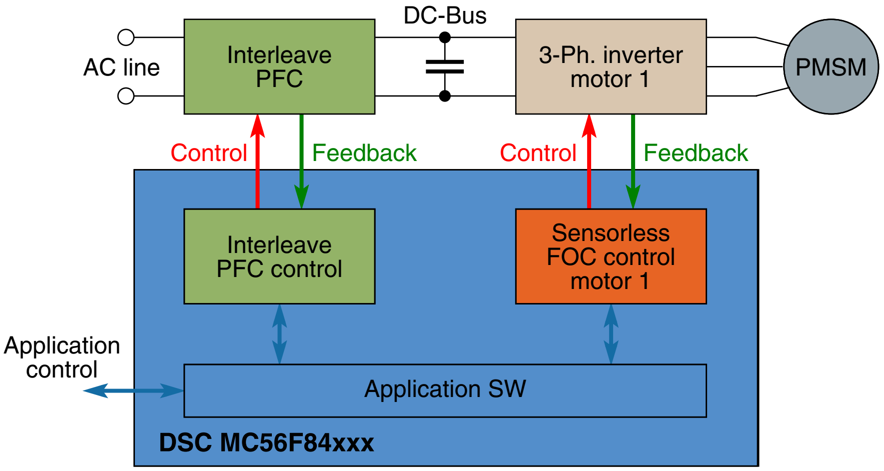

Figure 9. One Motor Control with PFC Stage

The main 3-phase motor with the PFC stage connection is in Figure 9. The main power circuit for the one motor control with PFC stage connection is shown in Figure 10.

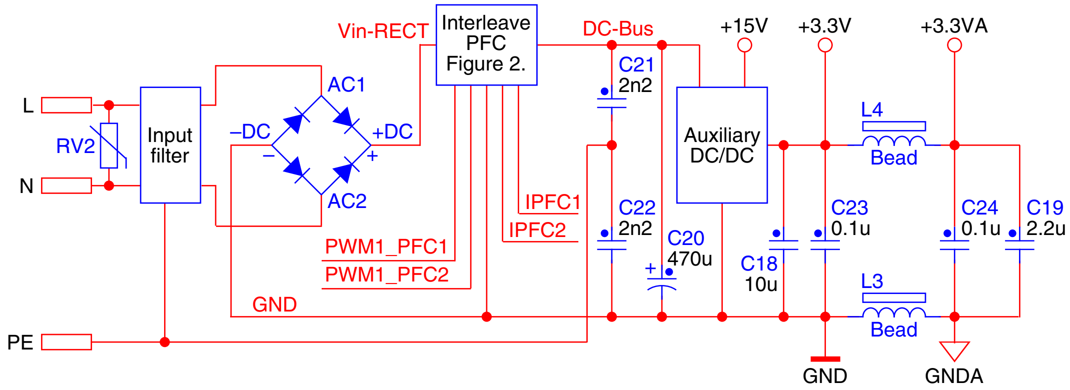

Figure 10. Power supply with interleaved PFC stage

The DSC power supply circuits and JTAG connection are the same as in previous configuration. It is shown in Figure 5. The measured currents and voltages are processed by the measurement amplifiers and connected to the control DSC as in Figure 11.

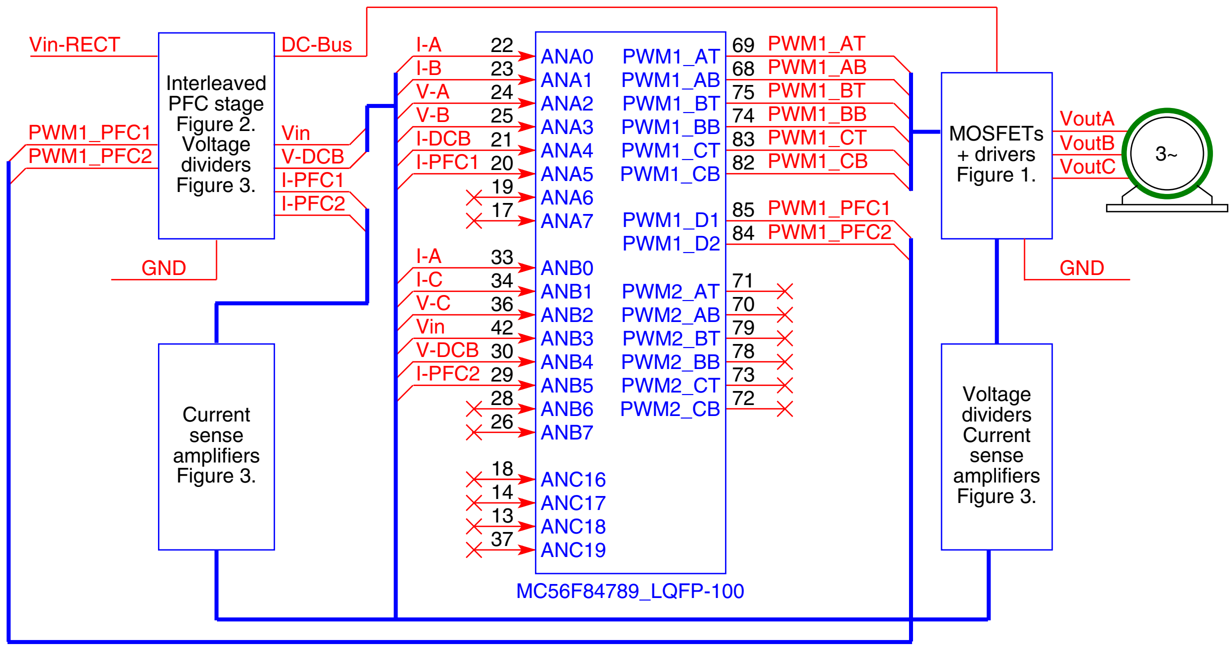

Figure 11. Measurement and control signals for one 3-phase motor with PFC

The difference to previous is only the PFC stage control PWMs and PFC currents measurement.

4.4 Two 3-Phase Motors with PFC Stage

This configuration is mostly used in the heating, ventilating and air conditioning (HVAC) appliances. This configuration comprises the two PMSM with PFC stage as shown in Figure 12.

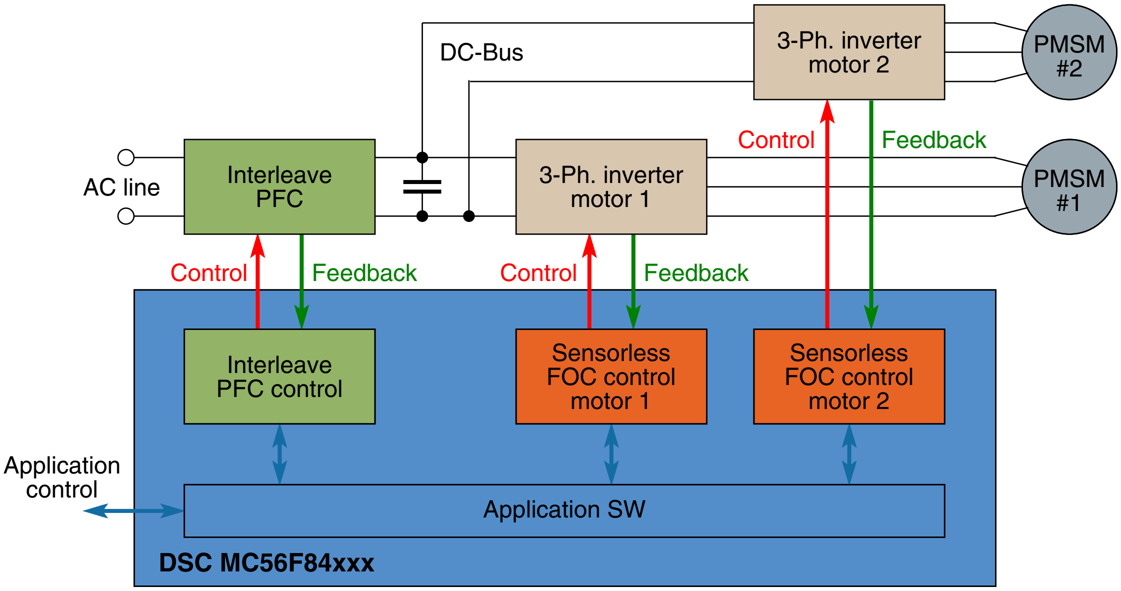

Figure 12. Dual Motor Control with PFC Stage

The hardware connection of the ADC and PWM pins of the control DSC is in Figure 13.

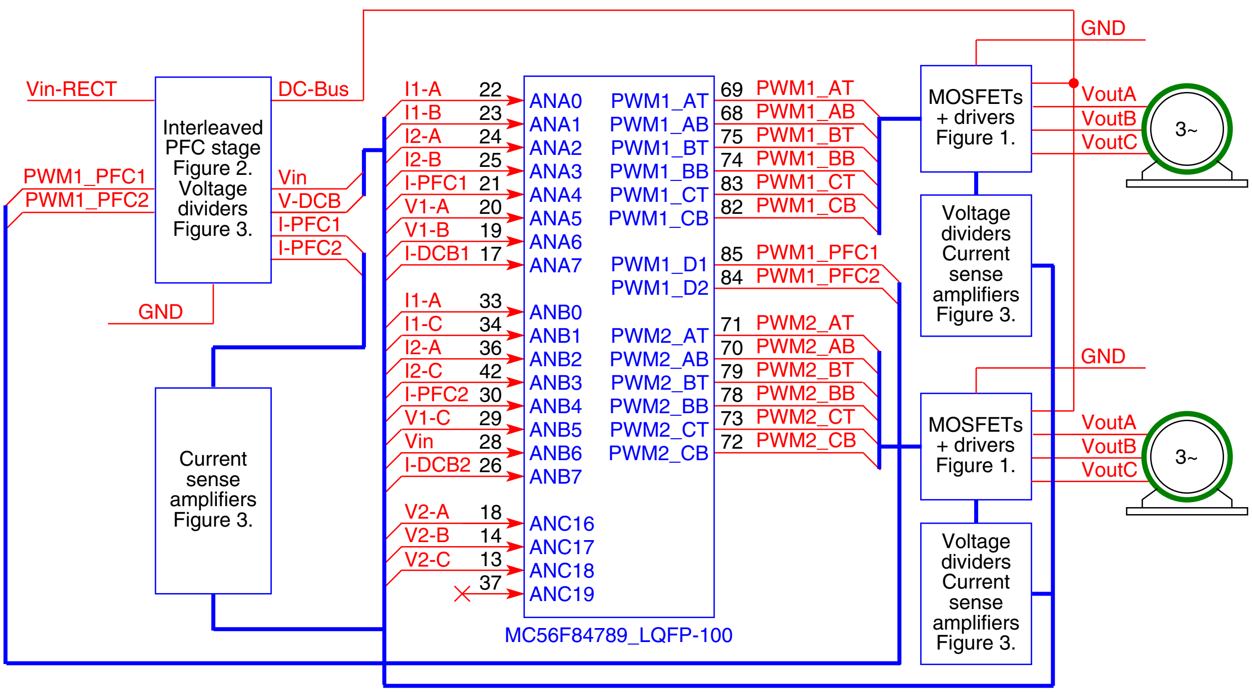

Figure 13. Measurement and control signals for two 3-phase motors with PFC

5 Conclusion

The application note suggests the proper connection of the DSC MC56F84xxx for motor control applications. Particularly it deals with ADC, PWM, current sensing and other necessary connections of pins of DSCs.

The main peripherals for this application are the ADC and PWM modules. The ADC module is used for all voltage/currents measurements. The ADC measurement moment must be properly set due to switching noise elimination. The ADC module provides many options for the right sampling time synchronization with the generated PWM signals. The PWM module generates the control signals for the power driver.

The right consideration must be done for each application regarding the package pinout. The lowest pin count package (48 LQFP) meets the minimum requirements for one PMSM control. The largest package (100 LQFP) can be used for the dual motor control with PFC stage. The internal cross-bar supports flexibility for the final pinout configuration for the each package.

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