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Application Note

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Using eFlexPWM Module for ADC Synchronization in MC56F82xx and MC56F84xx Family of Digital Signal Controllers

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Contents

1 Introduction....1
2 eFlexPWM as trigger unit....3
2.1 eFlexPWM configuration in motor control applications....4
2.2 Application example....5
3 Conclusion....6
4 References....7

1 Introduction

Synchronization between PWM module and analog-to-digital converter (ADC) is one of the key requirements in motor control and power conversion applications. These applications use pulse with modulation (PWM) to generate voltages or currents in the system and thus a ripple can be observed when system quantities are measured. The quantity ripple makes analog-to-digital conversion difficult since actual value of quantity corresponds to the moment of the ADC sampling. This issue can be solved by PWM to ADC synchronization. When the analog-to-digital conversion sample is taken just in the middle of PWM pulse, the ADC result corresponds to average value of the measured quantity.

The PWM to ADC synchronization is also necessary in situations when the current or voltage sensor is placed in the position where measured signal is not available during the whole PWM period. Typical example is current sensing using shunt resistors. As can be seen in Figure 1, the shunts are connected in series with source of bottom IGBT transistor in every phase. This means that voltage drop on the shunt, corresponding to the phase current, is available when only the bottom transistors are switched on. Therefore, the current measurement has to be synchronized with PWM signals too.

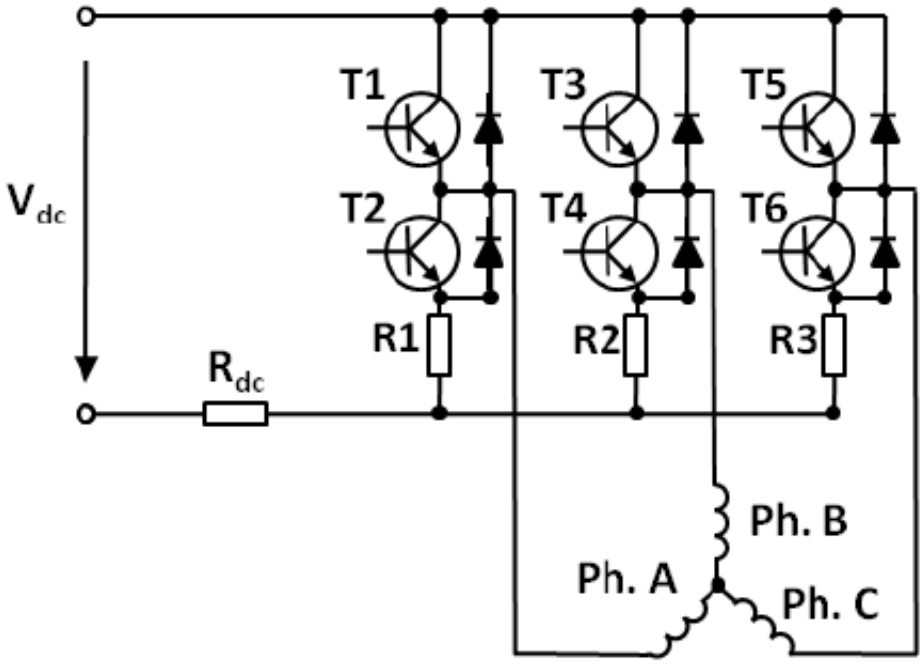

Figure 1. Typical usage of shunts for phase current measurement

Following are some new features available in the digital signal controller (DSC) MC56F82xx for PWM to ADC synchronization:

- Firstly, the ADC supports multi-trigger sampling. There is new ADC Scan Control Register (ADC_SCTRL), which controls individually for each sample, whether the sample for conversion is taken immediately or has to wait for the next trigger. Setting bit for corresponding sample means that the ADC waits for the trigger event to start the next conversion. This feature allows the user to convert any number of ADC channels in different times without CPU intervention until all the 16 samples are taken (there are 16 bits in ADC_SCTRL register).
- The second new feature, which brings much higher flexibility for ADC triggering, is a crossbar switch (XBAR). The functions of the crossbar switch are as follows:
  - The crossbar switch allows connecting any signal on the input side to any output side of the crossbar switch.
  - The crossbar switch interconnects many peripherals like eFlexPWM, ADC, Quad Timer, Comparator, and DAC.
  - The crossbar switch brings very high flexibility since the user can interconnect peripherals according to the application needs. An example of crossbar switch interconnection for DSC 56F82xx is shown in Figure 2.

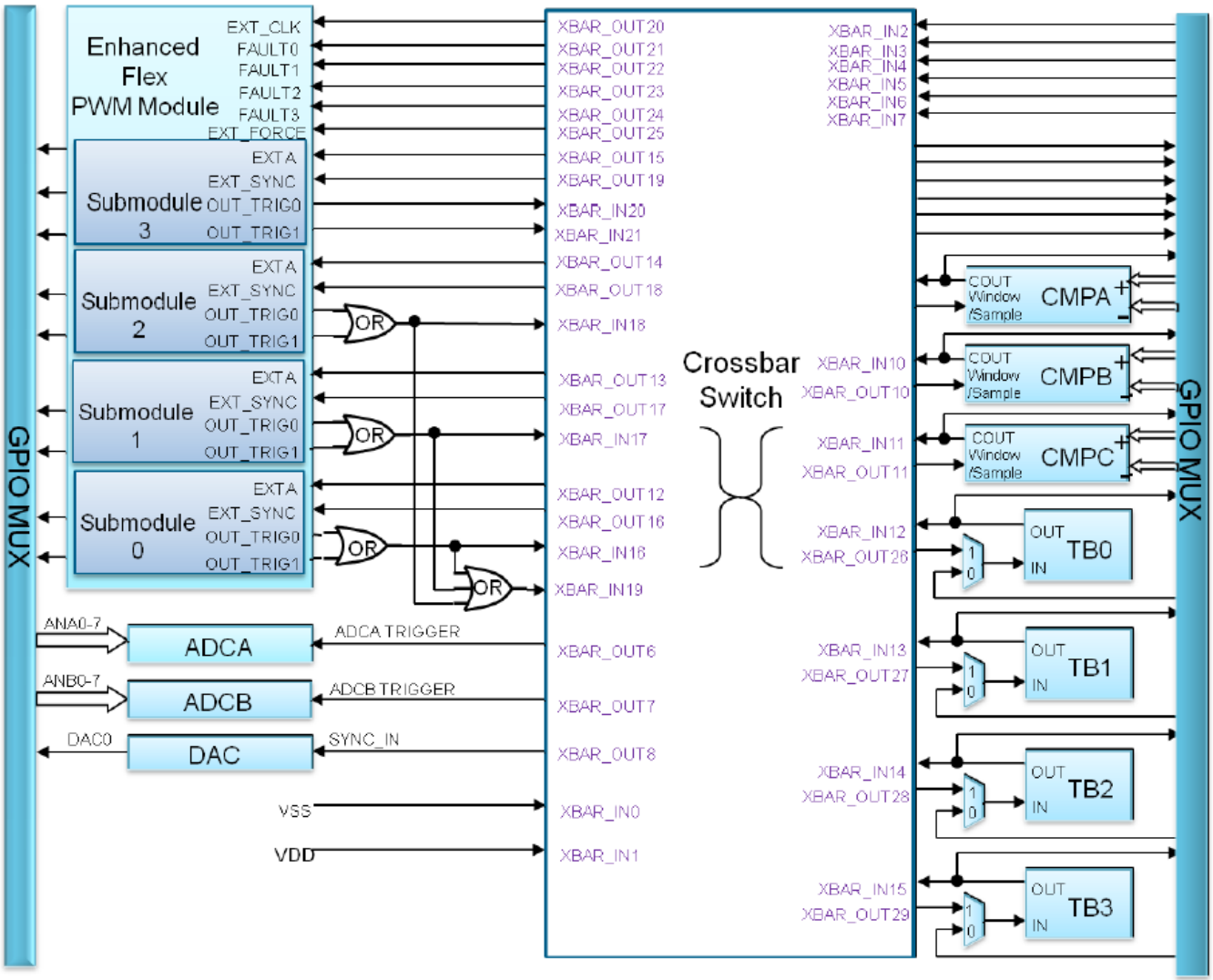

Figure 2. 56F82xx crossbar switch implementation

As seen in Figure 2, the ADC triggers are connected to crossbar switch outputs XBAR_OUT6 and XBAR_OUT7. The user can use any of the crossbar switch input signals as a trigger signal for the ADC module. This is different to previous digital signal controllers, where peripherals interconnection was fixed.

2 eFlexPWM as trigger unit

Another noteworthy change for the DSC users is the introduction of a new PWM module, called eFlexPWM on the latest DSCs such as MC56F82xx, and MC56F84xxx. This module brings much more flexibility for PWM signals generation like individual time base for each PWM submodule, individual control of every edge or high-resolution frequency, and duty cycle generation. These improvements make eFlexPWM module more suitable for digital control of power conversion applications.

The block diagram of one eFlexPWM submodule is shown in Figure 3. The submodule consists of one 16-bit counter as a time base and six compare registers. The submodule can generate up to 3 PWM signals PWMA, PWMB, and PWMX. The outputs PWMA and PWMB can utilize all available features like complementary generation with dead time, individual edges control, faults, software control, high resolution and others. The PWMX output is auxiliary output generating edge-aligned signal. If this output is not used, it can be configured as an input for the capture feature or sense a polarity of the current for the dead time compensation.

All the three submodule PWM outputs share the same time base and period configuration setting, which is defined by difference of Comparator 1 Value (VAL1) and Init register (INIT). The Compare 0 Value (VAL0) is used for duty cycle settings of PWMX output, or it can be used for mid-cycle reload signal generation. This signal can be generated anywhere during the PWM period on the top of a full reload at the end of PWM period. Both the signals are used to update all buffered registers by new values. The Comparator 2 and 3 values are dedicated for the output PWMA. The first value (VAL2) defines the position of rising-edge and the second value (VAL3) defines the position of falling edge of PWMA output. For proper PWM signal generation, both the VAL2 and VAL3 values have to be within the range defined by INIT and VAL0 registers and VAL3 has to be equal or larger than VAL2.

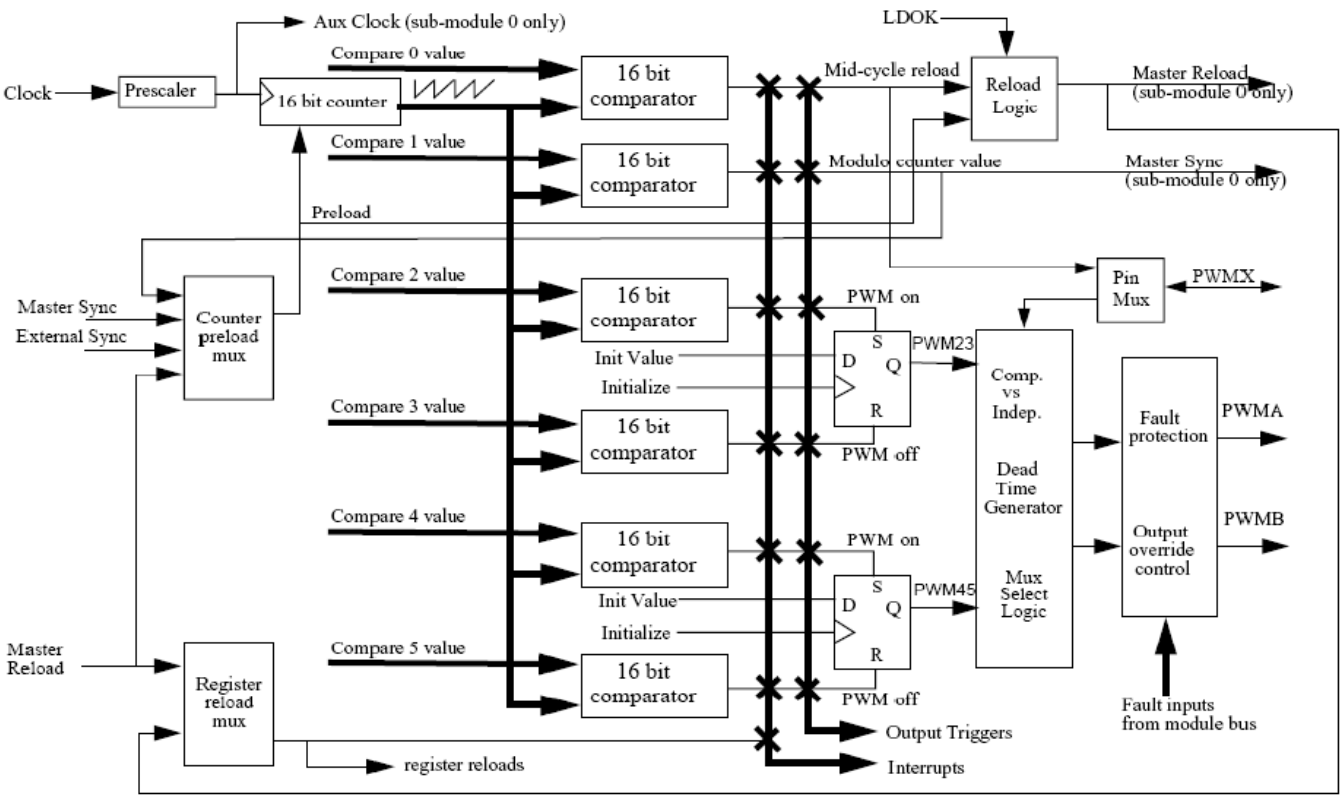

Figure 3. Block diagram of eFlexPWM submodule

In the same manner, the Comparator 4 and 5 values are dedicated for the output PWMB. The value VAL4 defines the position of rising-edge and the value VAL5 defines the position of falling-edge of PWMB output. For proper PWM signal generation, both the VAL4 and VAL5 values have to be within the range defined by INIT and VAL0 registers and VAL5 has to be equal or larger than VAL4. In case of complementary signals generation, VAL4 and VAL5, alternatively VAL2 and VAL3 don't need to be used since the complementary signal is generated by hardware.

Besides edge control, all compare events can be used for further purposes. The first one is interrupt generation, where every compare event can generate interrupt event. Secondly, every compare event can be used to generate trigger event. Every eFlexPWM submodule has two trigger outputs: OUT_TRIG0 and OUT_TRIG1. The trigger signals of VAL0, VAL2, and VAL4 are ORed to the output OUT_TRIG0 and trigger signals of VAL1, VAL3, and VAL5 are ORed to the output OUT_TRIG1. The trigger outputs from all the submodules are routed to the crossbar switch, specifically for every DSC family. The trigger outputs connection of DSCs 56F82xx can be seen in Figure 2.

2.1 eFlexPWM configuration in motor control applications

If the eFlexPWM module is used in motor control applications, not all the compare registers are used. The typical eFlexPWM configuration will be demonstrated on three most commonly used motor control applications:

- Sinusoidal control of 3-phase ACIM or PMSM

- Bipolar complementary switching for BLDC motor
- Unipolar independent switching for BLDC Motor

All PWM modulation uses the same hardware of 3-phase bridge depicted in Figure 1.

The AC induction and permanent magnet synchronous motor (PMSM) need to generate three pairs of complementary signals. Therefore, three eFlexPWM submodules are needed. The first submodule will be submodule 0 since this submodule can be used as a master. Next two submodules can be any combination of rest of the submodules. For this example, submodule 1 and 2 will be considered. For this configuration:

- The submodule 0 uses VAL1 for PWM period definition, VAL2 and VAL3 define duty cycle for phase A, and VAL4 and VAL5 are unused since complementary output is generated by complementary logic. VAL0 is also unused, or it can be used for half cycle reload generation.
- The submodule 1 and submodule 2 utilize VAL2 and VAL3 for duty cycle definition for phases B and C. Other compare registers VAL0, VAL4, VAL5 including VAL1 (the period of PWM signals is broadcasted from master submodule 0) remain unused.
- The submodule 3 is completely unused and can thus be used for other purposes. The summary of compare registers utilization can be seen in the following table.

Table 1. Usage of compare register values for eFlexPWM submodules

eFlexPWM submodules	Compare Register					
	VAL0	VAL1	VAL2	VAL3	VAL4	VAL5
Submodule 0	unused	used	used	used	unused	unused
Submodule 1	unused	unused	used	used	unused	unused
Submodule 2	unused	unused	used	used	unused	unused
Submodule 3	unused	unused	unused	unused	unused	unused

The bipolar complementary switching for BLDC motor has the same requirements for eFlexPWM configuration since three pairs of complementary PWM outputs are needed too. In case of unipolar independent switching, all the bottom transistors are switched on during the whole period. It means that software control feature can be utilized for the generation of bottom PWM signals and thus VAL4 and VAL5 comparators remain unused as well as for sinusoidal PWM generation or bipolar complementary switching for BLDC motors. Therefore, Table 1 is valid for all the three types of PWM modulations.

The analysis above shows that even if the eFlexPWM module is used for PWM modulation, there are still unused compare registers, which can used for trigger events generation.

2.2 Application example

The example of eFlexPWM and ADC triggering will be demonstrated on current measurement using shunt resistors in 3-phase inverter using 56F824x/5x (see Figure 1). Following steps will better demonstrate this application example.

1. To measure all the 3 phase currents, the current samples are taken twice per PWM period (see Figure 4). The first two samples are taken at beginning of PWM period. During this moment, all the bottom transistors are switched off and there is no current flowing through the shunts. The result of analog-to-digital conversion corresponds to offset at zero current and this value is used for zero offset compensation.

   The second conversion is taken in middle of the period where all the bottom transistors are switched on. Since some phase may have bottom transistor conducting for very short time, two phases with widest pulses are chosen. Therefore the current samples are changed based on actual duty cycle of all three phases. See Figure 4.

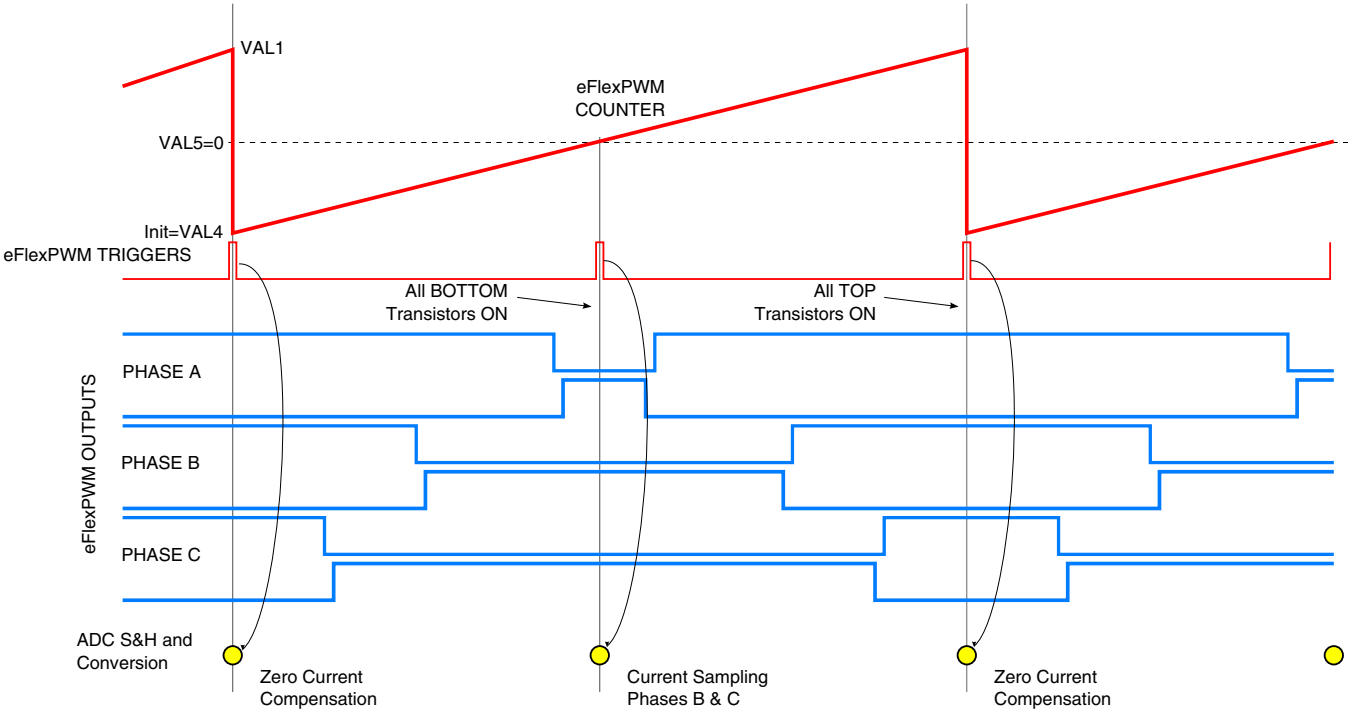

Figure 4. Current sampling using 3 shunts

2. To use the eFlexPWM as the trigger, the crossbar switch has to be configured in order to connect eFlexPWM trigger output to the input trigger of ADC. In this case, two triggers are required; so, the user can use any of the submodules, since every submodule has at least three unused compare registers (see Table 1). For this example, the submodule 0 is chosen and the crossbar switch is configured to connect input IN18 (TRIG0 ORed with TRIG1 of submodule 0) to the crossbar switch output OUT6 (ADCA TRIGGER). Since both the ADCs will run in parallel, there is no need to connect trigger signal to ADCB. See Figure 2.
3. The next step is to select compare registers for trigger generation. The user can select VAL4 to generate trigger at beginning of PWM period (VAL4 = INIT) and VAL5 to generate trigger event at the middle (VAL5 = 0). Considering that the counter is set in sign counting mode: INIT = -MODULO/2, VAL1 = (MODULO/2)-1, then the middle of period is at CNT = 0. To enable trigger generation, the corresponding bits in PWM Output Trigger Control Register (PWM_SMTCTRL) have to be set.
4. Following actions are needed to configure the ADC as the last step.
    a. Enable the hardware trigger (SYNC0 = 1), End Of Scan Interrupt (EOSIE0 = 1) in the ADC Control Register 1 (ADC_CTRL1) and simultaneous conversion (SIMULT = 1) in the ADC Control Register 2 (ADC_CTRL2).
    b. Then, configure SAMPLE0 and SAMPLE1 (ADC_CLIST1 register) to convert Phase X and SAMPLE4 and SAMPLE5 (ADC_CLIST2 register) to convert Phase Y, where X and Y are two phases with the widest pulse width. Since the current signals are bidirectional, the user can also configure corresponding offset registers, ADC_OFFST0, ADC_OFFST1, ADC_OFFST4, and ADC_OFFST5 to automatically subtract the offset from ADC results.
    c. Finally, set the corresponding bits in the ADC Scan Control Register (ADC_SCTRL). These settings ensure that the SAMPLE0 and SAMPLE4 are converted on the first trigger (VAL4) and samples SAMPLE1 and SAMPLE5 are converted on the second trigger (VAL5). After the last conversion, the interrupt is called and the user can process new data.

3 Conclusion

This application note describes the usage of eFlexPWM as a trigger unit. Typical configuration of eFlexPWM module in motor control applications doesn't utilize all compare registers in the eFlexPWM module and therefore are available for other purposes like trigger event generation. The flexibility of eFlexPWM module is also extended by crossbar switch which

allows user-defined interconnection among peripherals and thus allows connection of eFlexPWM module to ADC module. The application example shows peripherals configuration for the 56F82xx family of DSCs. However, the same approach can be used for any newer DSC like 56F84xxx or 56F82xxx.

4 References

The following reference documents are available on **freescale.com**.

- MC56F825XRM: MC56F825x/4x Reference Manual
- MC56F825X: MC56F825x / MC56F824x Digital Signal Controller Data Sheet

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