Driving an ACIM with the dsPIC® DSC MCPWM Module

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INTRODUCTION

This document presents an overview of the Motor Control PWM module (MCPWM) present on the motor control family of dsPIC30F Digital Signal Controllers. Code examples are included for a typical three-phase AC Induction Motor (ACIM) control application using a Three-Phase Inverter topology.

MCPWM MODULE

The scope of this document is limited to usage of the MCPWM Module. The information presented is based on a practical example. You should familiarize yourself with the features and functions of the MCPWM (see Section 15 of the *"dsPIC30F Family Reference Manual"* (DS70046)).

The inductance of the motor windings filters the current from a PWM voltage source as shown in Figure 1. Based on this principle we can generate sine waves with PWM signals to energize a three-phase ACIM, as we will see shortly in this document.

FIGURE 1: CURRENT WAVEFORM FILTERED BY THE MOTOR'S WINDINGS

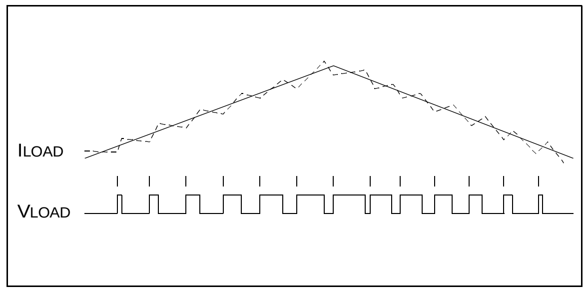
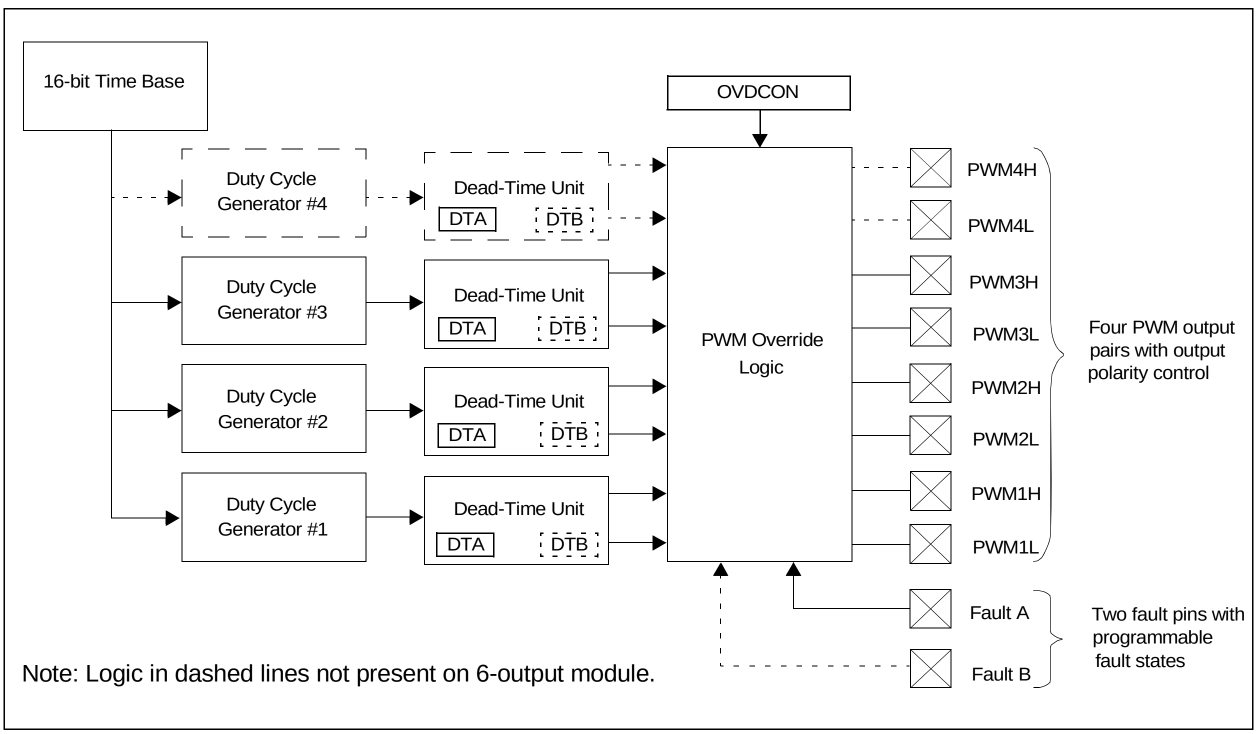


Figure 2 is an abbreviated block diagram of the MCPWM module showing how complementary pulses are generated for driving the ACIM in this example.

FIGURE 2: MCPWM BLOCK DIAGRAM



Duty cycle generators create pulses that contain the preprogrammed duty cycle information. Dead-time units offset the pulses to prevent shoot through in driving the inverter transistors. PWM override logic allows the output signals to be modified based on fault conditions and/or program instructions. For example, an output signal from this block can be inverted if negative polarity is selected or can be forced to a programmed value in the OVDCON register.

APPLICATION EXAMPLE

The application example consists of generating a 60 Hz three-phase signal to energize a three-phase AC Induction Motor. Figure 3 shows the topology used (a three-phase inverter). In this topology, six PWM outputs are connected to individual power transistors (MOSFETs or IGBTs):

The main requirement for the application example is to generate 60 Hz, three-phase sine waves with a 120° of phase shift. Based on a sine wave look-up table, different offsets are added with pointers to generate the three signals on the PWM pins. Each table entry represents a duty cycle value to be stored in the corresponding duty cycle registers.

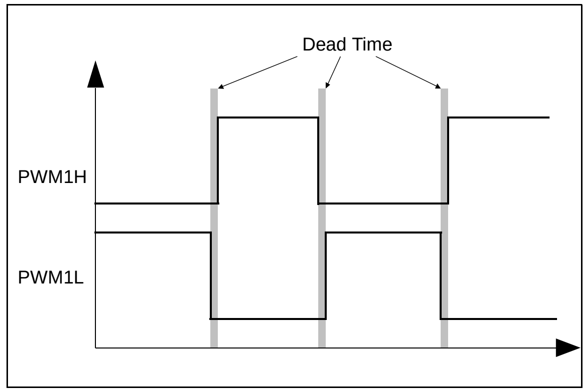
Initializing the MCPWM Module.

The following process will guide you through the selection of specific MCPWM module features needed to run the application example. A code example is included to show the actual registers and bits' names.

Step 1. Configure the MCPWM module for complementary outputs.

Since the Complementary mode is used to generate the sine waves, you'll need to add a slot of time in which both transistors PWMxH and PWMxL are off to prevent any shoot through. In this example, a dead-time value of 2 µs is inserted automatically after turning off one transistor and turning on its complementary one. Figure 4 shows the timing diagram of two complementary pin pairs with dead-time insertion.

FIGURE 4: COMPLEMENTARY PWM WITH AUTOMATIC DEAD-TIME INSERTION



Step 2. Use the PWM outputs in Center-Aligned mode.

The Center-Aligned mode is used in this example to avoid turning on three power transistors at the same time, thus reducing the noise generated by the power devices. Figure 5 shows a center-aligned time diagram.

FIGURE 3: THREE-PHASE INVERTER

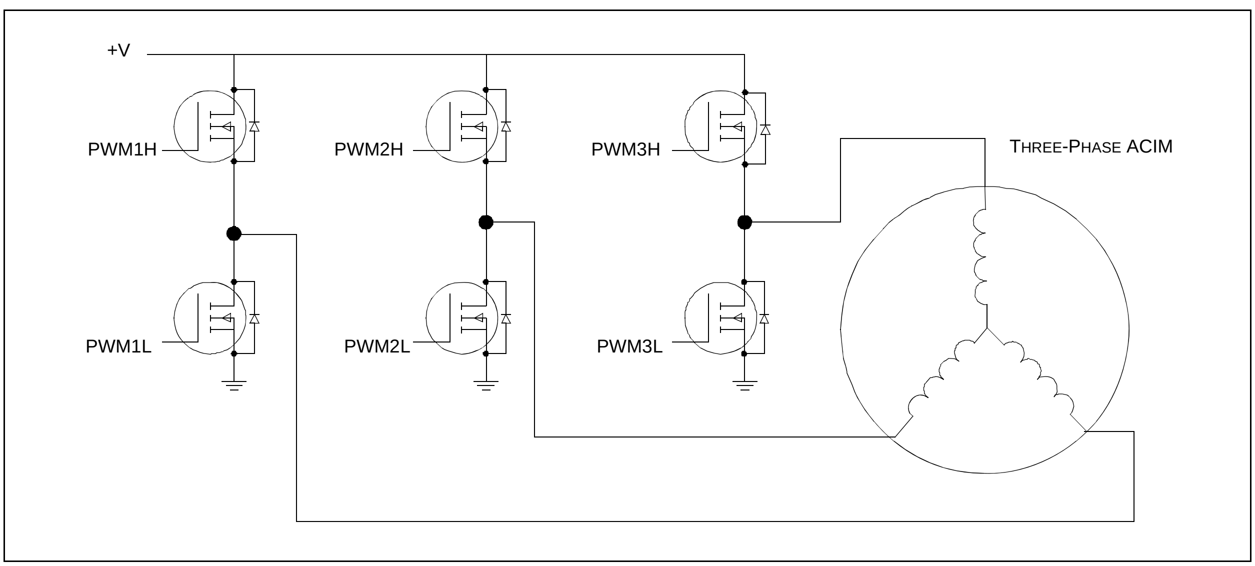
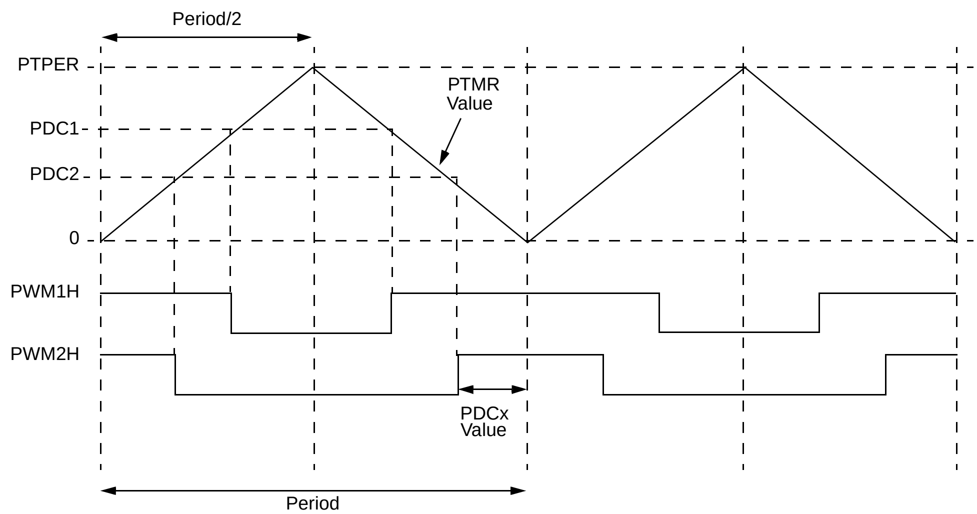


FIGURE 5: CENTER-ALIGNED PWM TIME DIAGRAM



As you can see from the figure, as long as the duty cycles (PDC1 and PDC2) are different, the turn-on time will be different. In Edge-Aligned mode, they would be turned on at the same time regardless of the duty cycle value.

Step 3. Avoid PWM audible noise.

The PWM frequency is configured to be 20 kHz to avoid audible noise, although frequencies above 15 kHz will be hard to perceive. The following formula was used to calculate the actual PTPER for Center-Aligned (up/down count) mode and 20 kHz.

$$PTPER = \left(\frac{F_{CY}}{F_{PWM}} - 1\right) \div 2$$

Based on the PWM configuration requirements previously described, Example 1 shows the code used to initialize the MCPWM module:

EXAMPLE 1: CODE FOR INITIALIZING THE MCPWM MODULE

```
#define FCY 20000000                   // 20 MIPS
#define FPWM 20000                     // 20 kHz
#define DEADTIME (unsigned int)(0.000002 * FCY)
#define _DES_FREQ 60                   // 60 Hz sine wave is required
#define _DELTA_PHASE (unsigned int)(_DES_FREQ * 65536 / FPWM)

void InitMCPWM(void)
{
    TRISE = 0x0100;                    // PWM pins as outputs, and FLTA as input
    PTPER = (FCY/FPWM - 1) >> 1;       // Compute Period for desired frequency
    OVDCON = 0x0000;                   // Disable all PWM outputs.
    DTCON1 = DEADTIME;                 // ~2 us of dead time @ 20 MIPS and 1:1 Prescaler
    PWMCON1 = 0x0077;                  // Enable PWM output pins and enable complementary mode
    PDC1 = PTPER;                      /* 0 Volts on Phase A. This value corresponds to
                                          50% of duty cycle, which in complementary mode
                                          gives an average of 0 Volts */
    PDC2 = PTPER;                      // 0 Volts on Phase B.
    PDC3 = PTPER;                      // 0 Volts on Phase C.
    IFS2bits.PWMIF = 0;                // Clear PWM Interrupt flag
    IEC2bits.PWMIE = 1;                // Enable PWM Interrupts
    OVDCON = 0x3F00;                   // PWM outputs are controller by PWM module
    PTCONbits.PTMOD = 2;               // Center aligned PWM operation
    Phase = 0;                         // Reset Phase Variable
    Delta_Phase = _DELTA_PHASE;        // Initialize Phase increment for 60Hz sine wave
    PTCONbits.PTEN = 1;                // Start PWM
    return;
}
```

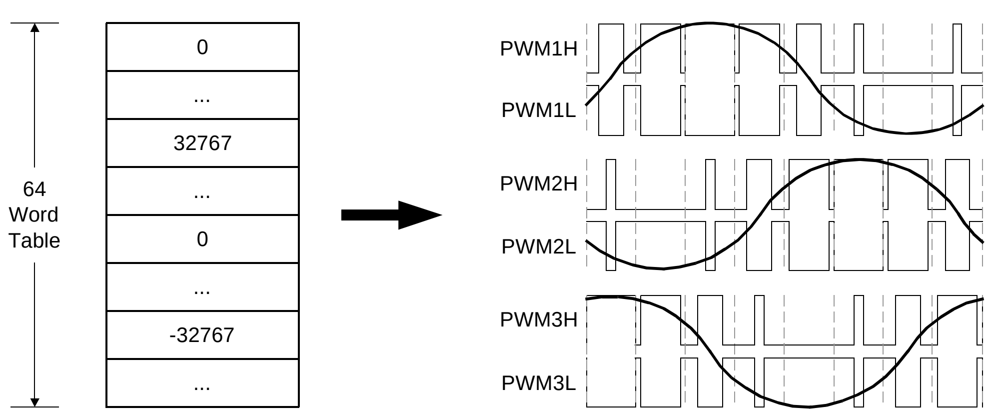
Driving Three-Phase ACIM with the MCPWM

This section of the document shows you how to generate a three-phase sine wave using the MCPWM features described in the previous section. A code example is provided to show the actual implementation of this application.

To generate the three phase outputs, sinusoidal data for a complete electrical cycle is provided in a 64-word table. The data is in 16-bit signed fractional format normalized to the range -1 to 1. A variable called `Phase` is used as a 16-bit pointer to the table with 0x0000 representing 0º and 0xFFFF representing 359.99º. At each PWM period interrupt (50 µs), the `Delta_Phase` variable is added to `Phase`. The value of `Delta_Phase` determines how fast the code moves through the sinusoidal data table and, as a result, sets the modulation frequency.

Figure 6 shows the look-up table and the three sine waves achieved with the MCPWM module. You can see the average voltage superimposed on the PWM signals, representing the voltage amplitudes to be fed to the motor's windings.

FIGURE 6: THREE-PHASE SINE WAVE GENERATION WITH LOOK-UP TABLE



The Delta_Phase variable is calculated as follows:

$$Delta\_Phase = 2^{16} \times \frac{Desired\_Frequency(Hz)}{F_{PWM}}$$

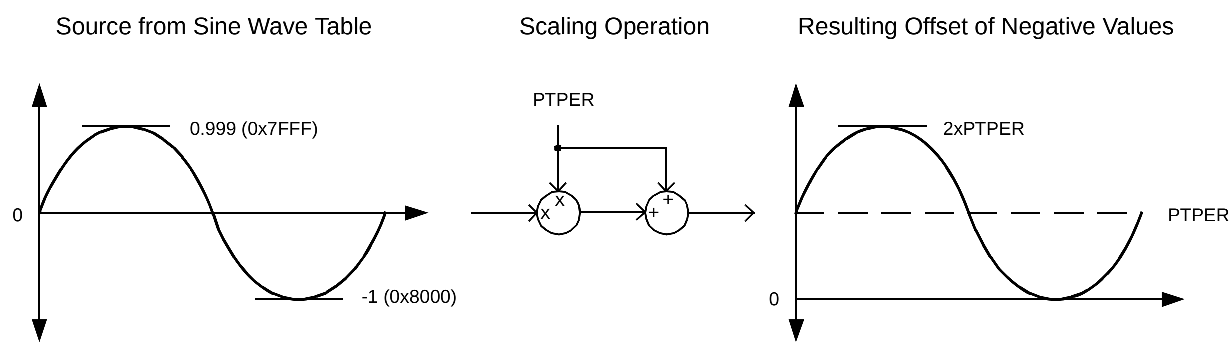
$$= 2^{16} \times \frac{60}{20000} = 196.6 = 197$$

After the Phase variable has been adjusted by Delta_Phase, two additional table pointers are calculated for the 2nd and 3rd motor phases by adding a constant offset to Phase. Assuming a 16-bit pointer, a value of 0x5555 provides a 120º offset and a value of 0xAAAA gives a 240º offset.

Next, the three 16-bit pointers are right shifted by 10 to get the most significant 6 bits of information. Since we only have a 64-entry table, we only need a 6-bit pointer. Different shift values would be used for tables of different sizes.

Finally, the three-phase pointers are added to the base address of the sine wave table stored in program memory and the sine values are retrieved. Now that we have the sine values, they need to be scaled for the desired modulation amplitude and PWM duty cycle range. First, the look-up values are multiplied by the value in the PTPER register to establish the amplitude. The PTPER value is then added to the amplitude to ensure that the resulting duty cycle value is positive. Figure 7 illustrates this scaling process. Since the duty cycle registers have twice the resolution compared to the PTPER register, a maximum value of 2xPTPER is required.

FIGURE 7: SCALING OF SINE WAVE TABLE FOR THE DUTY CYCLE REGISTERS



The modulation operations and the associated sine wave table are written so that you can reuse them in your own code. In practice, you may want to pre-scale the sine table data so you do not have to do as much scaling when modulating the sine wave.

The following code example performs the modulation for Phase B of the three-phase ACIM.

EXAMPLE 2: MODULATING PHASE B IN MCPWM INTERRUPT SERVICE ROUTINE

```
#define _120_DEGREES 0x5555
#define _240_DEGREES 0xAAAA
unsigned int Phase, Delta_Phase, Phase_Offset;
int Multiplier, Result;
. . .
    Phase += Delta_Phase;                // Accumulate Delta_Phase in Phase variable
    Phase_Offset = _120_DEGREES;         // Add proper value to phase offset
    Multiplier = sinetable[(Phase + Phase_Offset) >> 10];// Take sine info
    asm("MOV _Multiplier, W4");          // Load first multiplier
    asm("MOV _PTPER, W5");               // Load second multiplier
    asm("MOV #_Result, W0");             // Load W0 with the address of Result
    asm("MPY W4*W5, A");                 // Perform Fractional multiplication
    asm("SAC A, [W0]");                  // Store multiplication result in var Result
    PDC2 = Result + PTPER;               // Remove negative values of the duty cycle
```

The same code applies for the other two phases. For Phase A, the Phase_Offset value is 0 (0°). For Phase C, the Phase_Offset value is 0xAAAA (240°).

Notice that the multiplication is coded in assembly. This is done to take advantage of the fractional multiplication available in the dsPIC® DSC.

CONCLUSION

This document describes how you can use the dsPIC Motor Control PWM module specifically for AC Induction Motors. The code examples illustrate the actual implementation. Figure 8 shows the resulting voltage waveform of one motor phase filtered by an external RC filter. Figure 9 shows the RC filter used to get the filtered signal displayed in Figure 8.

FIGURE 8: OSCILLOSCOPE VIEW OF PWM VOLTAGE AND CORRESPONDING DUTY CYCLES

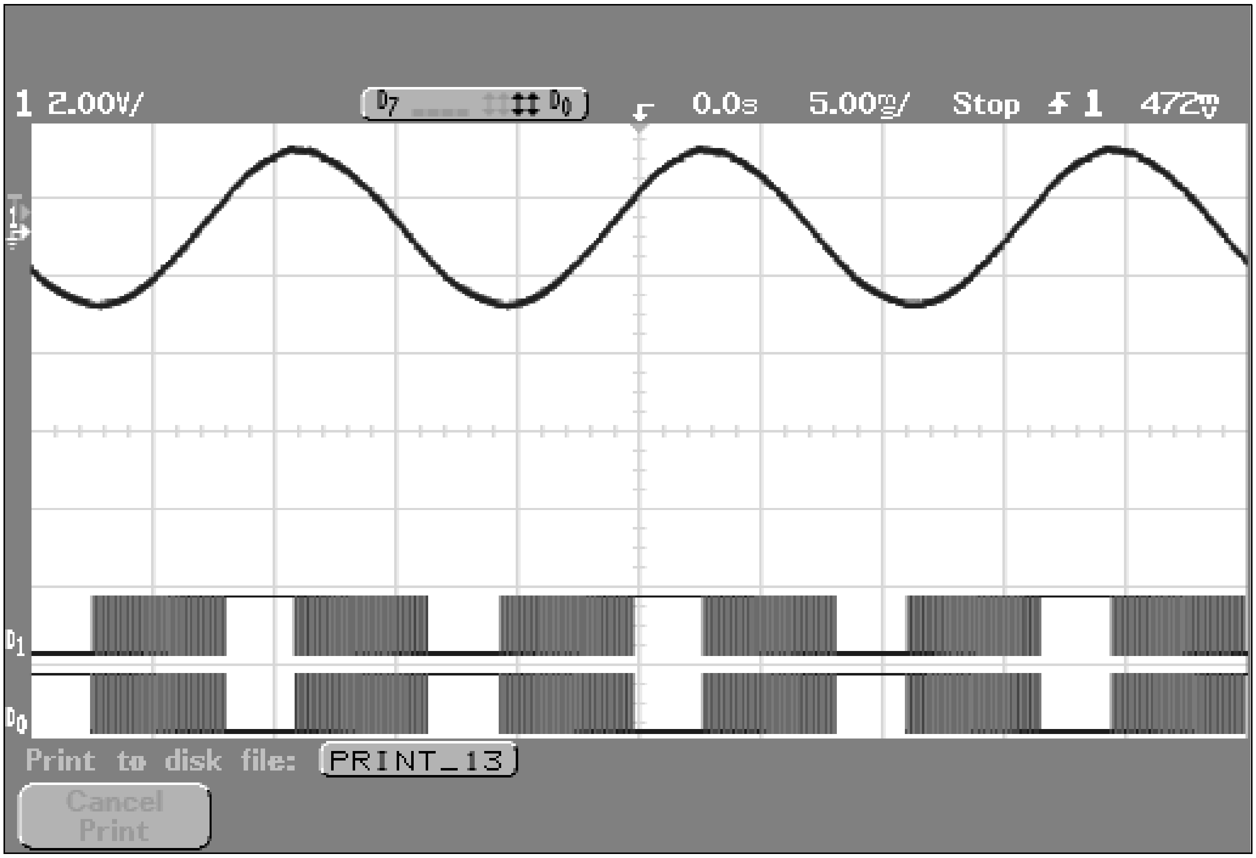
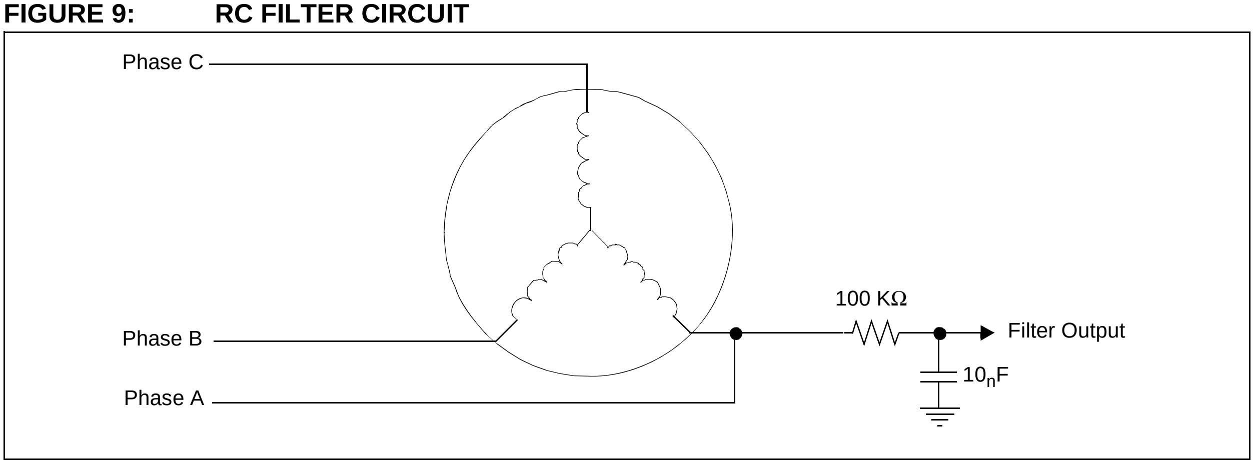


FIGURE 9: RC FILTER CIRCUIT



Note:	The code examples presented in this document were developed and tested on a dsPIC30F4012 device using Microchip MPLAB® IDE 7.11 and MPLAB® C30 Compiler v1.31.

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