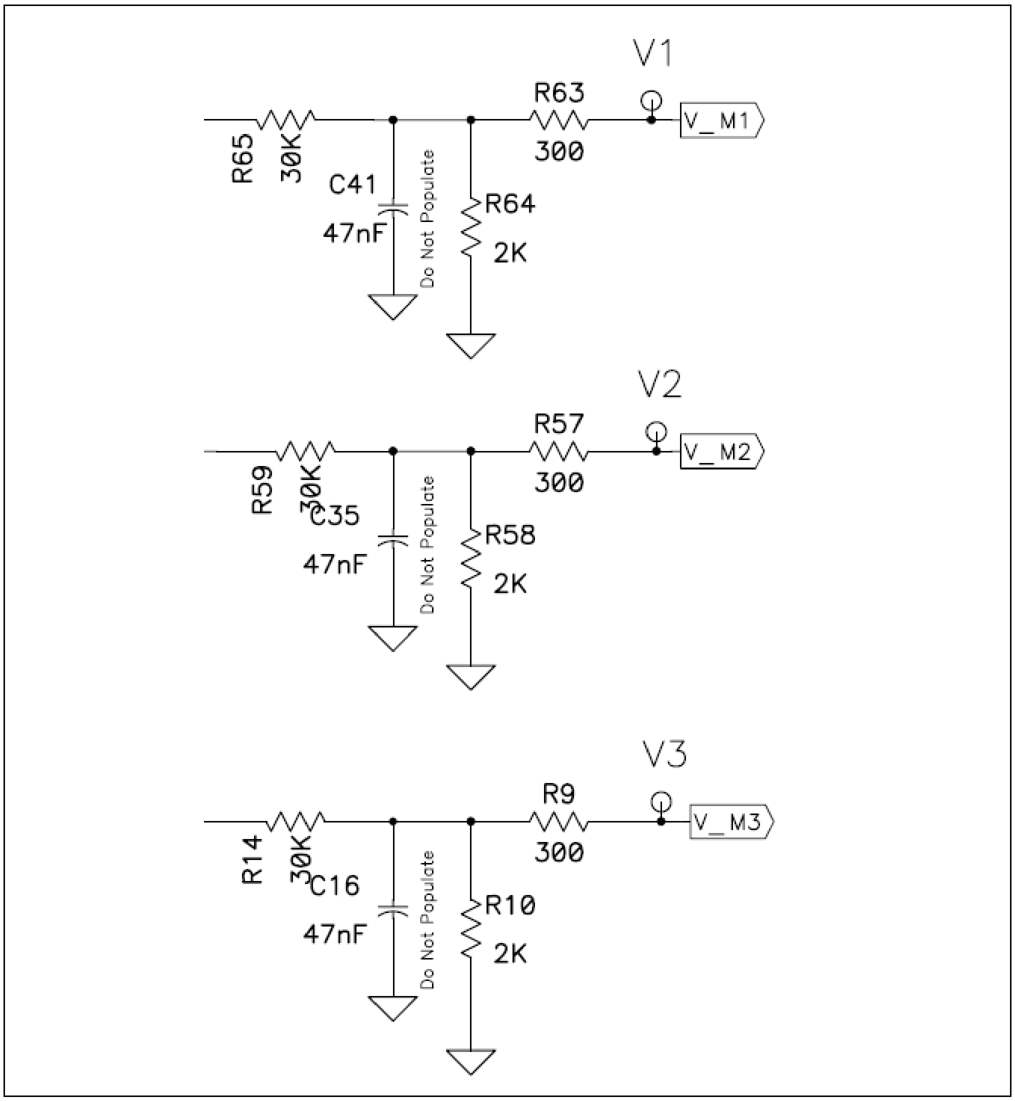
AN1160 Tuning Guide

1.1 SETTING HARDWARE PARAMETERS

It is required to scale the motor phase voltages through a resistor network in order to make them compatible with the maximum and minimum ADC input voltage levels as specified in the device data sheet.

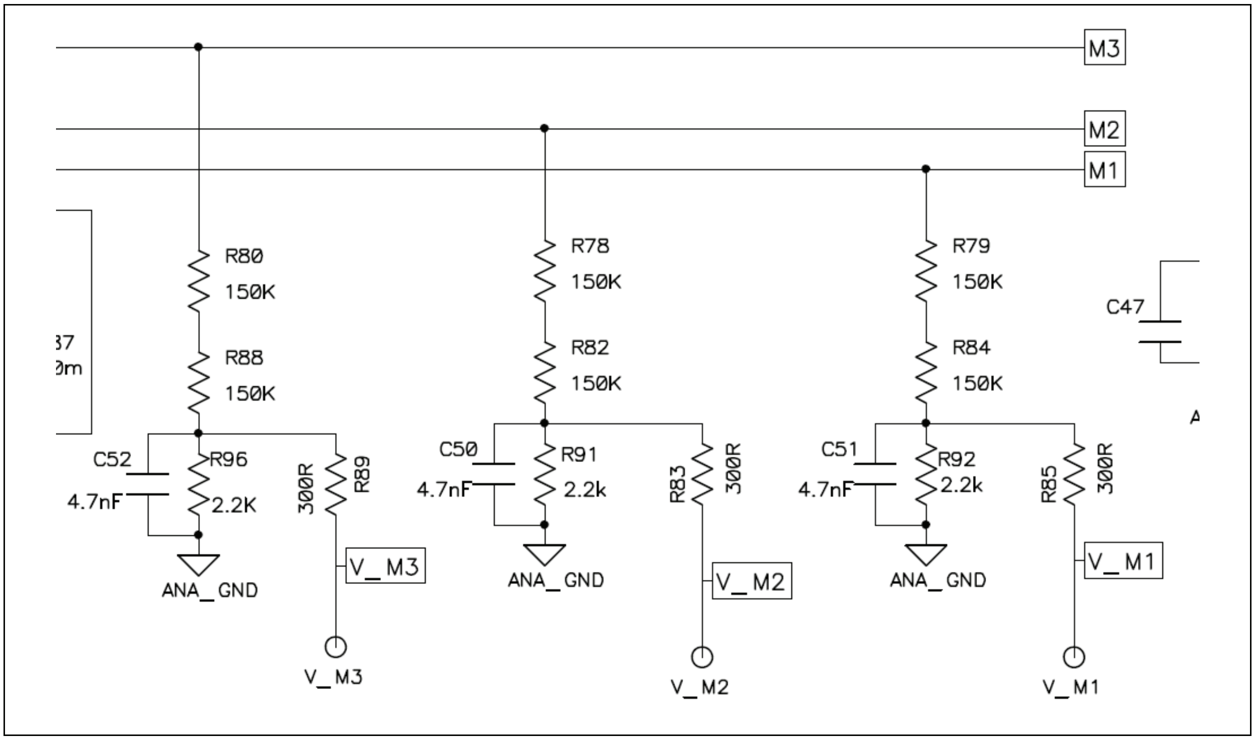
Figure 1-1 shows a typical circuit for a VBUS equal to 48V. Figure 1-2 shows a typical circuit for a 280V motor.

FIGURE 1-1: SIGNAL CONDITIONING CIRCUITRY FOR THE LOW-VOLTAGE MOTOR PHASE



This is the typical signal conditioning circuit for a VBUS equal to 48V.

FIGURE 1-2: SIGNAL CONDITIONING CIRCUITRY FOR THE HIGH-VOLTAGE MOTOR PHASE



This is the typical signal conditioning circuit for a VBUS equal to 400V.

It is required to sample the motor voltage phase signals simultaneously; therefore, they have to be connected to ADC input pins in which the CH1, CH2, CH3 sample and hold circuits can be used. These channels can be AN0, AN1, AN2 or AN3, AN4 and AN5.

1.2 SOFTWARE PARAMETERS

All of the configurable parameters are defined in the `UserParameters.h` file. The parameters are classified into three different categories: basic, advance, and derived. Figure 1-3 shows these parameters and Table 1-1 provides descriptions of each parameter.

FIGURE 1-3: SOFTWARE PARAMETERS

```
/*Timing DEFINES*/
#define DESIRED_MIPS        40
#define FIN                 7.3728e6
#undef  XTAL
#define PWM_FREQUENCY       20e3

/*Motor Control Definitions */
/*START-UP SEQUENCE PARAMETERS*/
#define MAX_PWM_TICKS  1230
#define RAM_UP_DELAY   1
#define MAX_DUTY_CYCLE_PERCENTAGE 100
#define MIN_DUTY_CYCLE_PERCENTAGE 2
#define PHASE_ADVANCE_DEGREES 5
#define BLANKING_COUNT 5

/*Close Loop Defines*/
#define CLOSELOOPMODE
#define PROPORTINAL_GAIN    2500
#define INTEGRAL_GAIN       256
#define DIFFERENTIAL_GAIN   0

/*Hardware definitions*/
#define S3             !PORTBbits.RB4
#define S2             !PORTAbits.RA8

/*************************ADVANCE DEFINI
#define TIMER1_PREESCALER   256
#define TIMER2_PREESCALER   256
#define SAMPLING_POINT_AT_LOWSPEEDS  25
#define SAMPLING_POINT_AT_HIGHSPEEDS 75
```

TABLE 1-1: SOFTWARE PARAMETER DESCRIPTIONS

Software Parameter	Description
DESIRED_MIPS	This macro defines the operating MIPS of the dsPIC device.
FIN	This macro defines the input clock frequency utilized by the system clock circuitry.
XTAL	If this macro is defined, the dsPIC device utilizes an external crystal as the source for the input clock. The FRC clock is selected when this macro is not defined.
PWM_FREQUENCY	This macro sets the output frequency of the PWM module.
MAX_PWM_TICKS	This macro sets the number of pulses applied in the forced commutation process utilized for breaking the motor's stand-still inertia. The possible value could be from 1 to 65535. This value is set according to the motor and load characteristics.
RAMP_UP_DELAY	This macro sets the delay required to switch from the forced commutation mode to sensorless mode. This delay is useful when the motor is attached to high-inertia loads such as fans with large blades.
MAX_DUTY_CYCLE_PERCENTAGE	This macro limits the maximum PWM duty cycle. It is expressed in PWM cycles.
MIN_DUTY_CYCLE_PERCENTAGE	This macro sets the duty cycle for the start-up sequence. It is defined in PWM cycles. Once the motor is running this number also limits the minimum duty cycle that can be applied to the motor.
CLOSELOOPMODE	When defined, this macro enables the speed controller. If it is disabled, the motor will run without the speed controller.
PROPORTIONAL_GAIN	This macro sets the P gain for the speed PID controller.
INTEGRAL_GAIN	This macro sets the I gain for the speed PID controller.
PHASE_ADVANCE_DEGREES	Phase advance angles to get the best motor performance or surpass the nominal speed.
BLANKING_COUNT	Sets the blanking count expressed in PWM cycles used to avoid false zero-crossing detection.
S3	This macro defines the I/O port used to poll the push button S3.
S2	This macro defines the I/O port used to poll the push button S2.

1.3 SETTING START-UP PARAMETERS

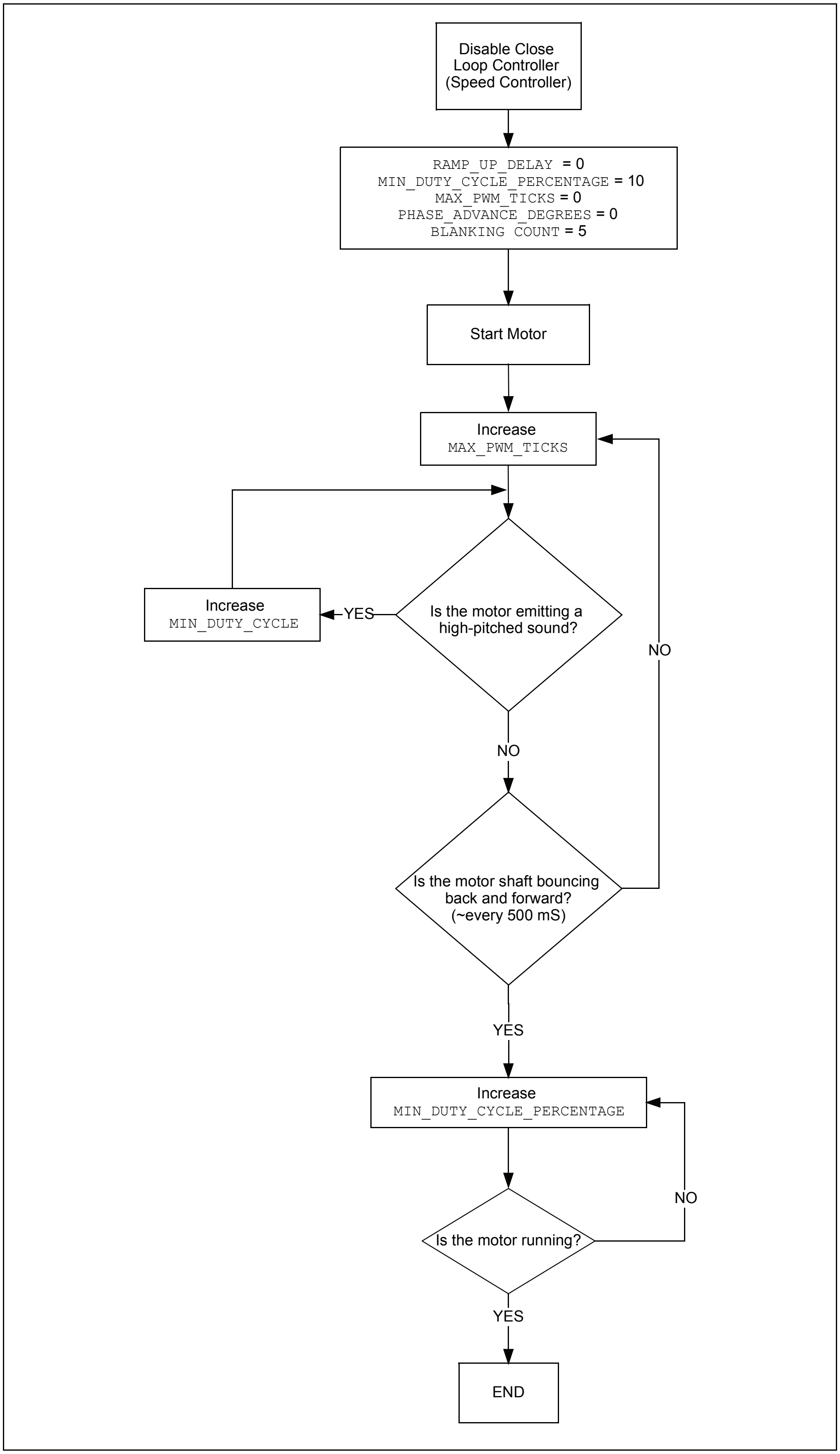
In order to determine the start-up parameters it is required to follow the described procedure.

1. Disable the speed loop controller. It is possible to disable this controller by removing the CLOSELOOPMODE definition. If DMCI with RTDM is used to control the motor, make sure the “ENABLE PI” button is OFF.
2. Set the reference speed (using the pot or the DMCI slider, depending on which SW version is running), “maximum PWM ticks”, “Phase Advance”, and “ramp up delay” values to 0. Set “Blanking Count” to 5.
3. Next, we are going to determine the correct values for “minimum duty cycle” and “maximum PWM ticks”. This is a trial-and-error process that depends on the motor and load characteristics.
4. Turn the motor ON by pressing S2 (non-DMCI version) or by turning ON the START/STOP button on DMCI.
5. Slowly increase (steps equal to 10 units) the “maximum PWM ticks” value. Stop increasing the “maximum PWM ticks” value when the motor shaft starts bouncing backward and forward.
6. If the motor shaft is not bouncing backward and forward, but instead is emitting a high-pitched sound, increase the “minimum duty cycle” by 10 unit steps and repeat steps 4-6 until the motor shaft is bouncing backward and forward.
7. The value “minimum PWM duty cycle” is close to the correct the start-up value when the motor shaft is bouncing back and forward. At this point it is required to find the minimum duty cycle in order to completely break the stand-still inertia.
8. Increase (using one step at a time) the “minimum PWM duty cycle”, and stop when the motor is continuously spinning.
9. Save the current “minimum PWM duty cycle” and “maximum PWM ticks”.
10. Stop the motor.
11. Start the motor using the saved “minimum PWM duty cycle” and “maximum PWM ticks” for the start-up sequence. The motor should be running.

Note: In some applications where high-inertia loads are attached to the motor is required to use a delay allowing the software make a smooth transition from the start-up sequence to sensorless mode. This delay is set by the “ramp-up delay” value. Increase or decrease this value as required by the application, specifically when the motor shaft it is not bouncing after trying different combinations of “minimum PWM duty cycle” and “maximum PWM ticks” values.

Figure 1-4 shows the start-up tuning procedure flow chart

FIGURE 1-4: TUNING PROCEDURE FOR THE START-UP SEQUENCE



1.4 ADVANCE TUNING PARAMETERS

The other tuning parameters such as the PI gains, the Phase Advance Angle, and the Blanking count number requires a better understanding of the algorithm used in the application note. Please refer to application note AN1160 *"Sensorless BLDC Control with Back-EMF Filtering Using a Majority Function"*.

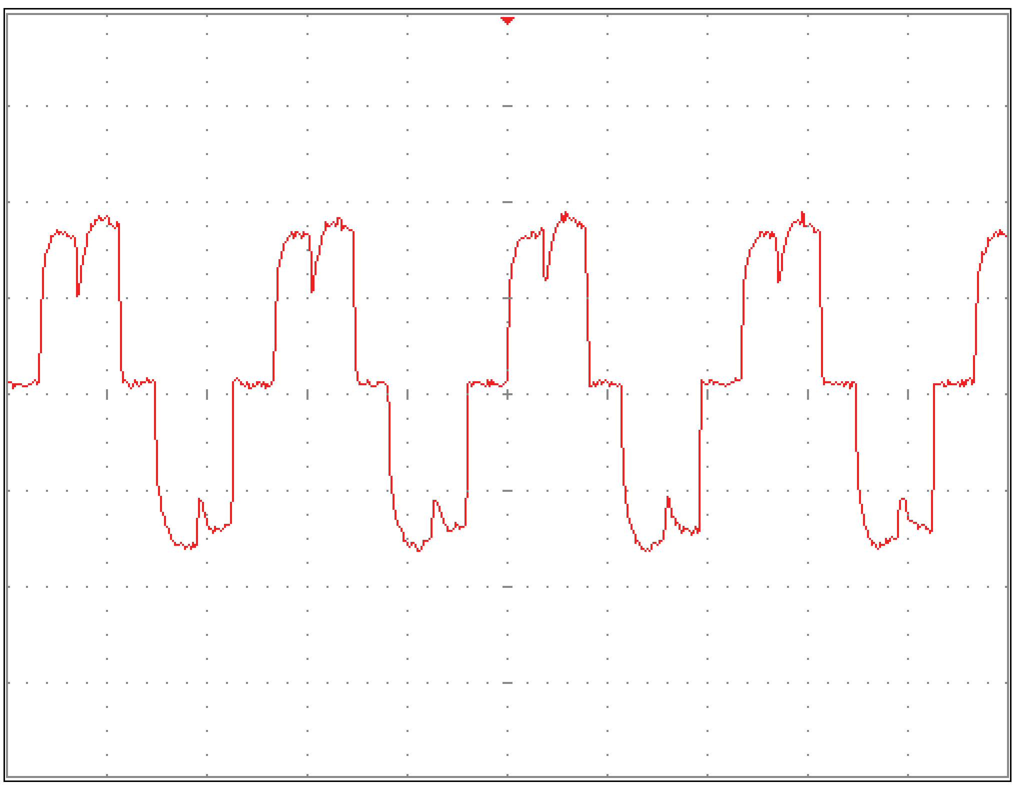
Tuning the close loop gains P and I can be done using multiple methods. Please refer to Wikipedia and search for "PID controller" and go to the section "Loop Tuning" for more information, or use the following link to access the information directly:

http://en.wikipedia.org/wiki/PID_controller#Loop_tuning

It is possible to improve the performance of the algorithm by increasing the phase advance angle and the blanking counter. To do so, it is required to observe the current waveform using a current probe and a oscilloscope.

1. Attached the current probe to any of the motor phases.
2. Start the motor.
3. Increase the motor speed slowly and stop at ¼ point of the maximum rated speed.
4. Change the phase advance and blanking counter values in order to get the current waveform as close as possible to Figure 1-5 when full load is applied to the motor.
5. Observe the current waveform while increasing the speed to ¼ of full speed.
6. Repeat steps 4-5 until the motor reaches the maximum rated speed.
7. The current waveform at this point should be similar in shape as Figure 1-5 in a wide speed range.

FIGURE 1-5: DESIRED PHASE CURRENT WAVEFORM



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