AN1449
APPLICATION NOTE

ST6200C UNIVERSAL MOTOR DRIVE SOFTWARE

by Microcontroller Division Application Team

INTRODUCTION

This application note describes the software of a low-cost phase-angle motor control drive system based on a ST6200C microcontroller and a BTB16-600CW snubberless triac. The application has been developed by STMicroelectronics and is available as a low-cost evaluation board UMC01EVAL.

This board can be widely used in many applications such as vacuum cleaners, power tools, food processors and lighting dimmers. The microcontroller implements the following functions:

- **Speed control:** the motor speed is set by a potentiometer on the board. With a look up table, the MCU can convert speed commands to firing angle delay times. The power delivered to the motor can be adjusted by changing the firing angle with reference to the voltage zero crossing signal.
- **Soft start:** This reduces the motor inrush current at start-up.
- **Mains Period Measurement:** In order to reduce system cost, a RC oscillator is used on the UMC01EVAL board as the MCU clock source. However its frequency can vary up to +/-20% because it is highly dependent on power supply voltage and temperature. To control the motor accurately, the mains power line period is measured and used as a time base.

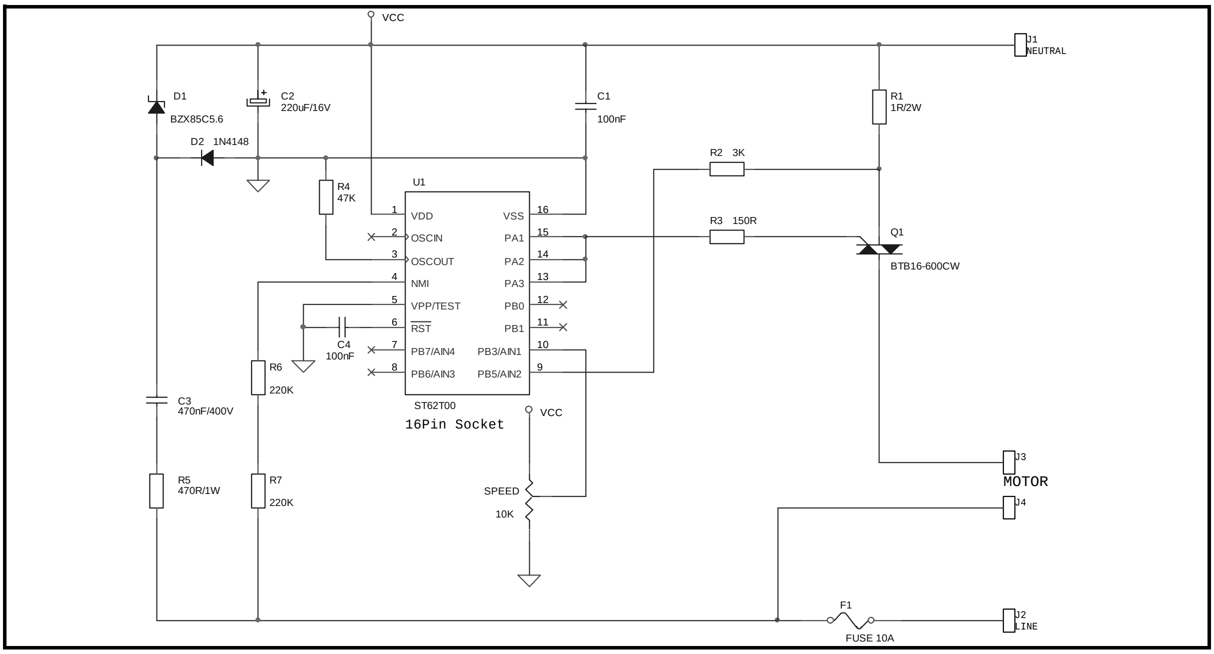
1 HARDWARE DESCRIPTION

1.1 GENERAL INFORMATION

The schematics of universal motor control board are shown in Figure 1. On this board, a low cost capacitive power supply generates +5V voltage for the ST6200C MCU and its application circuit. The motor speed control is managed by the ST6200C 8-bit MCU. The MCU clock is generated by on-board RC network. The internal 8-bit timer is used for the triac triggering control. The voltage zero crossing event is detected by two current limiting resistors (R6 & R7). The microcontroller triggers the snubberless triac BTB16-600CW directly with its 20mA outputs. Three high sink outputs can supply 60mA gate currents (I_{GT}=35mA). This board is able to drive a universal motor up to 1500W.

1.2 BOARD SCHEMATICS

Figure 1. UMC01EVAL Board Schematics



The hardware environment of the MCU has the following features:

- The MCU oscillator is implemented by an on-board RC network.
- No external reset circuit is used, this function is handled by the Low Voltage Detector option of the ST6200C.
- The voltage zero crossing event is detected through current limiting resistors (R6 & R7).
- R1 is reserved for future use. It must be replaced by a jumper when the board is running in open loop mode. In closed loop, it is used as a shunt resistor. It can measure the motor peak current.

2 MAIN PROGRAM

2.1 RC OSCILLATOR

In most applications, the MCU internal clock is supplied by a quartz crystal or a ceramic resonator. On this board, for cost reasons, it has been chosen to generate the system clock with an external resistor (the capacitor is implemented internally). However as a result of this choice, clock accuracy is only about +/-20% because the RC oscillator frequency is highly dependent on supply voltage and temperature variations. For more details, please refer to the Clock and Timing Characteristics Section of the ST6200C datasheet.

2.2 MAINS PERIOD MEASUREMENT

To obtain a more accurate clock source for driving the motor, the AC power line period is measured by the microcontroller. It is used as a system clock reference. The voltage zero crossing detection is performed by the ST6200C NMI interrupt with two current limiting resistors (R6 & R7). The interrupt (falling edge only) is generated at each negative voltage zero crossing event. It triggers the internal 8-bit Timer Counter Register (TCR) to measure the power line period. The result is stored in the T50HZ register. In 220V/50Hz applications, the value of T50HZ register corresponds to 20ms when the timer input clock division factor in the Timer Status Control Register (TSCR) is 64. The same value corresponds to 10ms when the timer input clock division factor is 32.

2.3 TIMING DEFINITION OF MAIN PROGRAM

The basic principle of the phase angle control algorithm is very simple. The ST6200C can detect the beginning of a full wave by detecting the negative voltage zero crossing event, after which it can calculate the phase angle, load the phase delay time PHASE in the 8-bit Timer Counter Register (TCR) and start the timer counting.

When the timer expires, the Timer Counter Register (TCR) is reloaded with a value in T50NEW register which is equivalent to the duration of one half cycle (e.g. 10ms at 50Hz), after which the first TRIAC triggering pulse is generated. Be aware that the value in the T50HZ register must be compensated with a look up table (RCTAB) in order to eliminate the fluctuation of the RC oscillator frequency within one full wave cycle. The compensated value is stored in the T50NEW register. To obtain the duration of a half cycle, we can use the same value in the T50NEW register and divide the corresponding timer input clock frequency by 2. It can be easily implemented by selecting the division factor of prescaler bits in the Timer Status Control Register (TSCR).

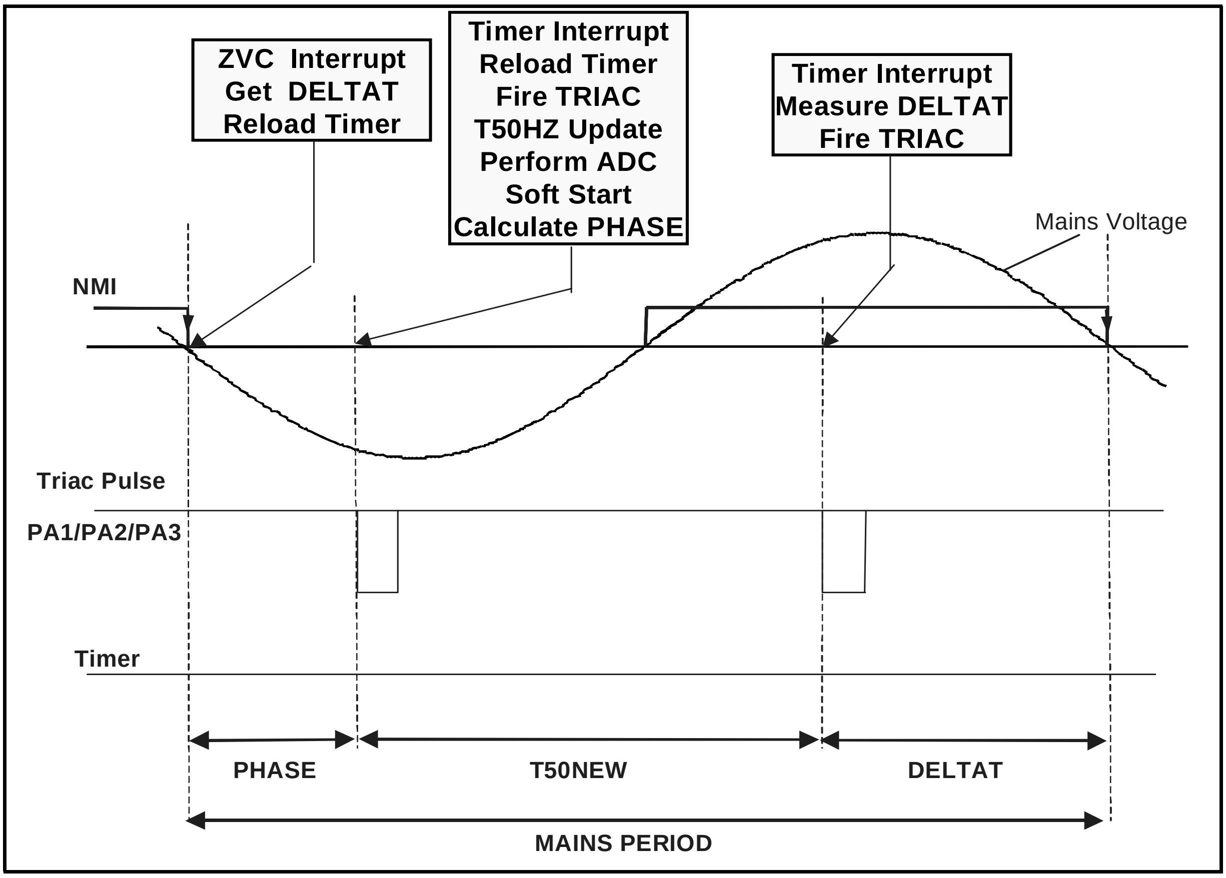
The time base T50HZ of the power line period is averaged every 16 full wave cycles (e.g. 320ms at 50Hz) in order to eliminate the influence of the RC oscillator. After that, the potentiometer measurement is performed with the internal A/D converter. The new speed command goes through the ramp up or down subroutine and speed look up table (VREFTB). The new phase angle in the PHASE register for the next cycle is computed. In addition, as mentioned above, the full wave timer value in register T50HZ must be compensated with the look up table (RCTAB) at different phase angles. This new value is stored in the T50NEW register.

When the half-cycle timer reaches zero, the second triac triggering pulse is generated. After that, the Timer Counter Register (TCR) is reloaded with 255 and starts counting. It is used as a capture to measure the duration from the second triggering pulse to the next voltage zero crossing event.

When the next voltage zero crossing interrupt occurs, the timer will be stopped by software. The duration from the second gate pulse to the zero crossing interrupt is stored in the DELTAT register. The full wave time will be equal to the sum of DELTAT, T50NEW and PHASE.

In total, one mains full wave period is divided into three parts: phase angle (PHASE register), half wave period (T50NEW register) and the rest (DELTAT register). The timing definition of main program is shown in Figure 2.

Figure 2. Timing Definition of Main Program



3 GATE PULSES

3.1 GENERAL DESCRIPTION

The gate current pulses are generated during the main program (refer to Figure 2). Appendix 1 gives the flowchart of the main program. As soon as a ZVC event is detected, the ST6200C reloads the timer with the phase angle delay time and starts the timer. When the timer reaches zero, the first gate triggering pulse is generated. The timer is reloaded and enabled with a value of one half-cycle. When the timer reaches zero, the second gate triggering pulse is generated within one full wave cycle.

3.2 PHASE ANGLE CALCULATION

To eliminate the timer clock variations due to voltage and temperature drift, the timer clock must be synchronized with the line voltage zero crossing. The power line period is measured by the ST6200C internal 8-bit timer. The resulting half cycle period is stored in the T50HZ register and used as the system clock. This number is then divided by 256, which results in 256 steps per half wave. With this division, 256 discrete phase angles are possible. This results in a resolution of 0.7 degrees. The actual phase angle PHASE is calculated as follows:

$$PHASE = \frac{T50Hz \times Vref}{256}$$

Dividing by 256 is simply implemented by considering the Most Significant Byte of the multiplication result of T50Hz and speed reference (Vref). A look-up table relating the delay time to the power requirement contains 64 different levels. The conduction time of the triac can be varied from 1.6ms to 9.2ms for a 50Hz application. The user can easily adjust the minimum and maximum power levels by changing the look up table.

3.3 GATE PULSE GENERATION

A universal motor is an inductive load. The motor current and input voltage are not in phase. The triac will turn off at the current zero crossing. To reduce component cost, the phase shift between current and voltage is not measured but can be adjusted by defining the maximum speed constant v_max. This constant should be decreased if the phase shift between voltage and current is too large.

3.4 INTERRUPT SERVICING TIME

The timer is not started immediately when an interrupt request occurs. This is because some instructions are executed before starting the timer. For example, before starting to count the first phase angle time, the program must run the NMI interrupt routine, save the DELTAT result, reload the timer and restart the timer. This takes 33 CPU cycles. To take the code execution time into account, we should convert it to the timer counter value (Tcode).

As we know, the MCU oscillator frequency (f_{CPU}) is divided by 13 to drive the CPU core. Therefore, "N" CPU cycles execution time is 13xN/f_{CPU} seconds. The MCU oscillator frequency (f_{CPU}) is divided by 12 to drive the internal timer, and then it is divided by the division factor programmed in the TSCR register. In this software, the division factor is 32 during the main program. Therefore, one unit timer counter equals 12x32/f_{cpu} seconds. We can easily work out the relationship between N cycles of code execution time and the timer counter value (Tcode), as shown below:

$$Tcode = \frac{N \times 13}{fcpu} \times \frac{fcpu}{12 \times 32} = N \times \frac{13}{384}$$

For example, the code execution time for 33 cycles approximately equals one unit of the timer count.

4 SUBROUTINES

4.1 POWER ON RESET

After each RESET interrupt, a complete initialization procedure is executed. This subroutine configures the Port A & Port B, Timer, A/D Converter, Interrupt Option Register and Status Flag Registers. It waits 100ms for the supply stabilization, and then it measures the mains period. The flowchart of this subroutine is shown in Appendix 1.

4.2 SOFT START

The soft start subroutine is entered when an acceleration or deceleration event occurs. The soft start feature enhances the life of bulbs, reduces coil stresses in motors, and extends the life of most loads. It can reduce the inrush current and prevent voltage fluctuations and flicker in the power supply (Refer to Flicker Norm EN61000-3-3).

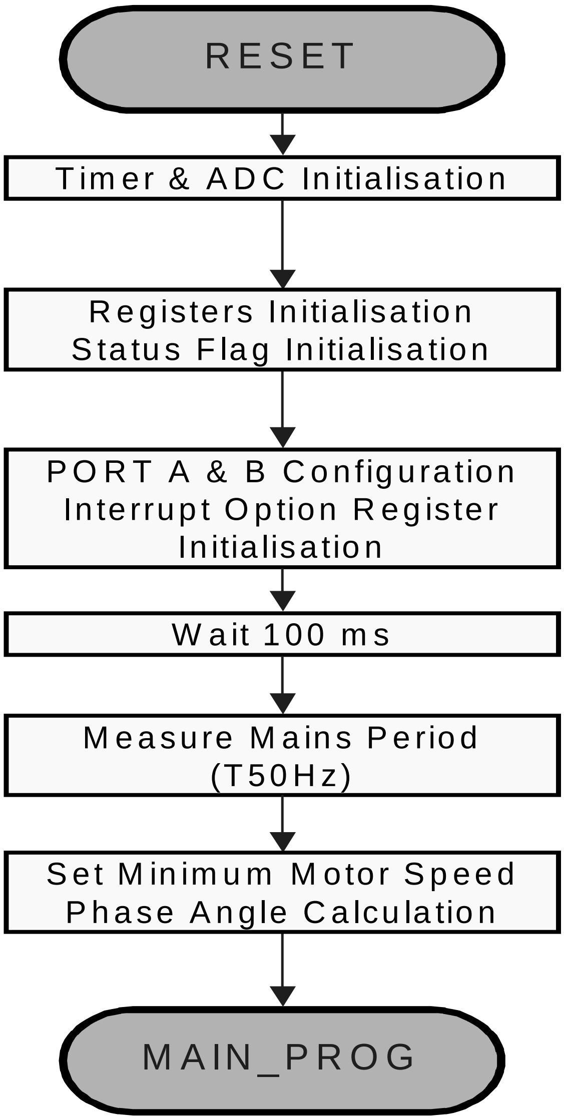
This subroutine in fact changes the slope of the speed command. The slope is the same for the accelerating and decelerating edge. It can be modified by changing the step constant. This flowchart is shown in Appendix 3.

5 CONCLUSION

This application note describes the software of a low cost universal motor control system. It is intend to help you to use this software as a basis for developing your own motor drive and to adapt it to your own requirements. The software is tested with the Raisonance RIDE ST6 Version 6.0.1 Assembler. For other assemblers the software must be adapted.

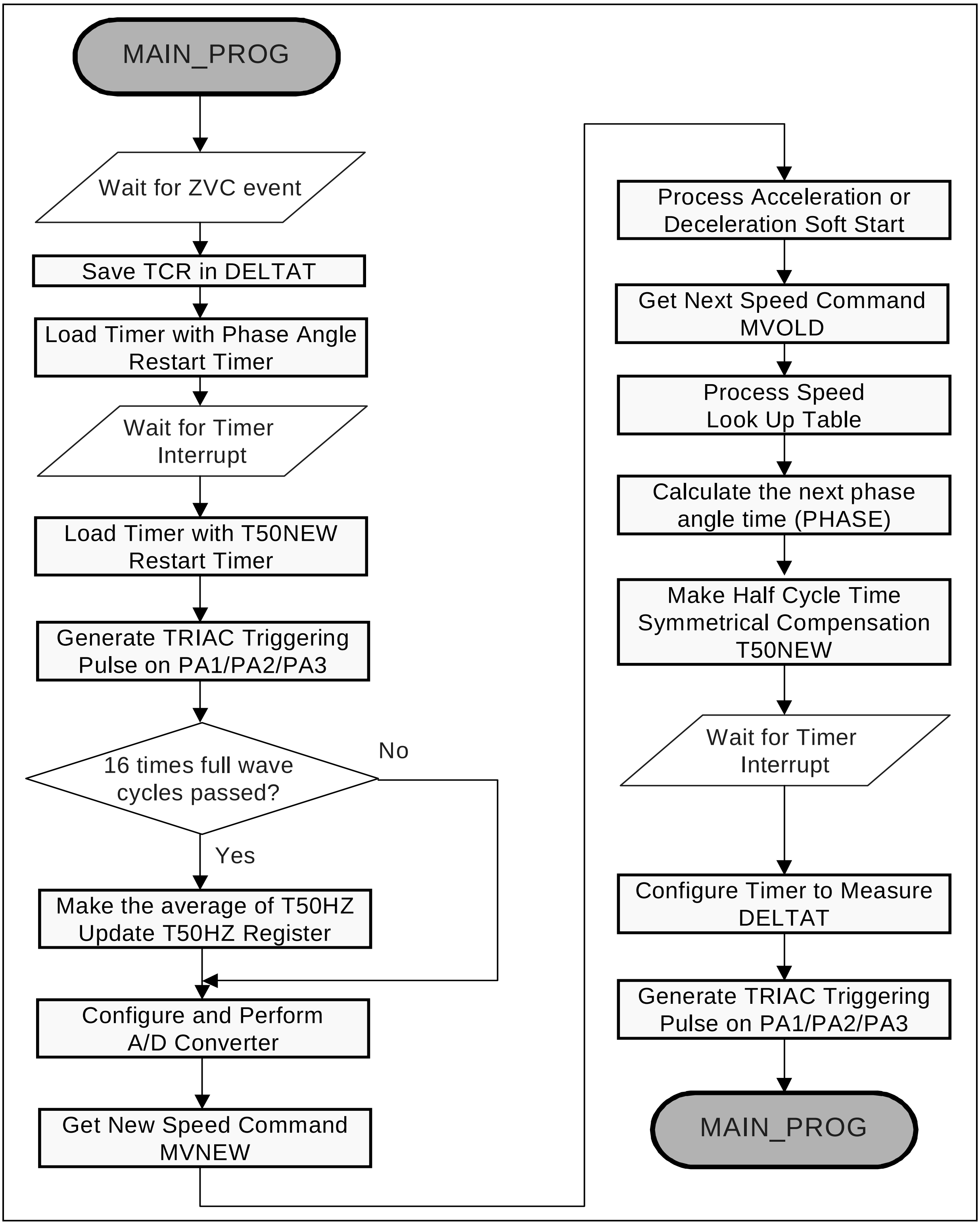
APPENDIX 1 - POWER ON RESET FLOWCHART

Figure 3. Power on Reset Flowchart



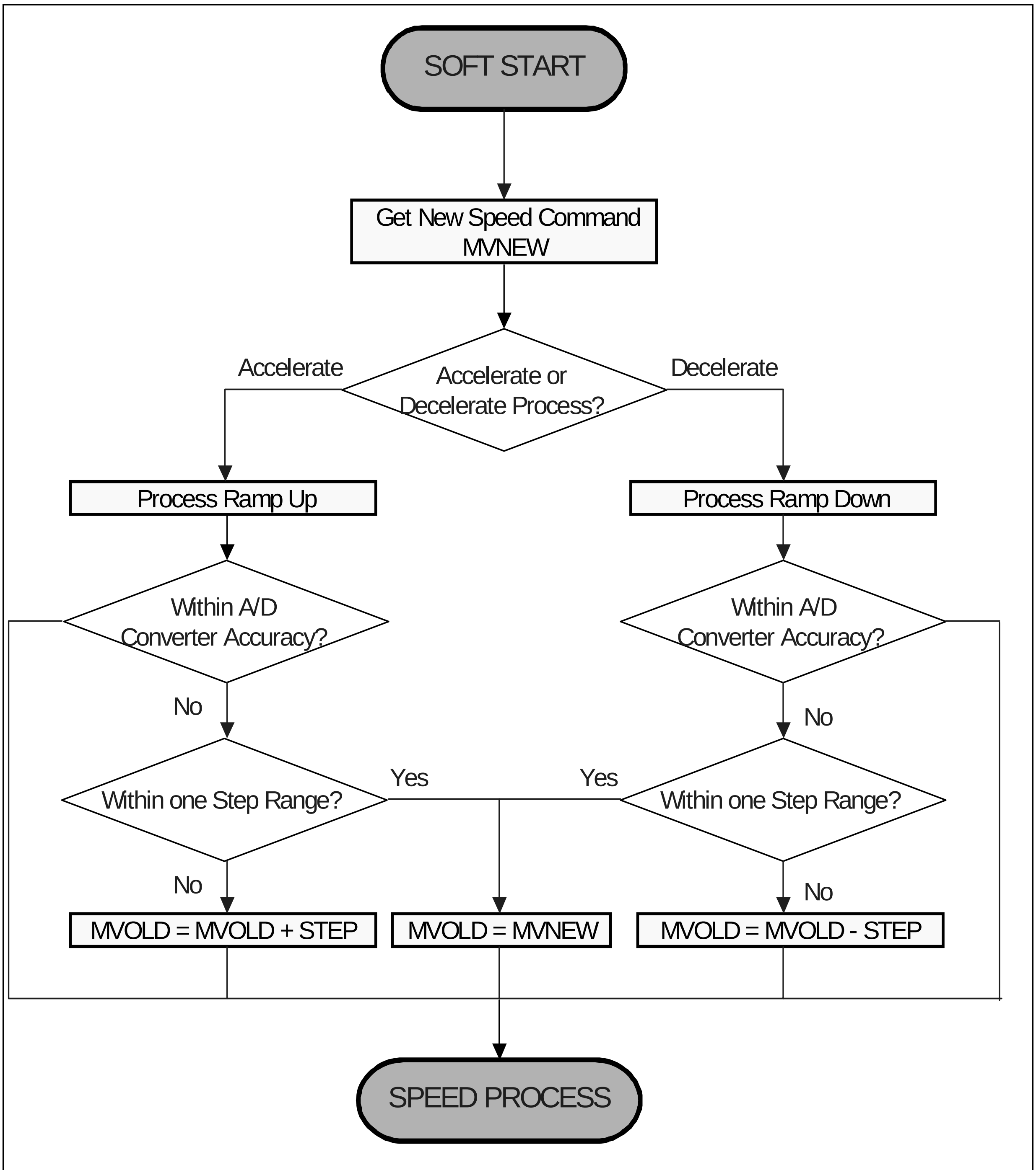
APPENDIX 2 - MAIN PROGRAM FLOWCHART

Figure 4. Main Program Flowchart



APPENDIX 3 - SOFT START FLOWCHART

Figure 5. Soft Start Flowchart



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