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Application Note

78K0 Universal Motor with Chopper Control

Document No. U17101EE1V0AN00
Date Published April 2004

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NOTES FOR CMOS DEVICES

① PRECAUTION AGAINST ESD FOR SEMICONDUCTORS

Note:

Strong electric field, when exposed to a MOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop generation of static electricity as much as possible, and quickly dissipate it once, when it has occurred. Environmental control must be adequate. When it is dry, humidifier should be used. It is recommended to avoid using insulators that easily build static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work bench and floor should be grounded. The operator should be grounded using wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions need to be taken for PW boards with semiconductor devices on it.

② HANDLING OF UNUSED INPUT PINS FOR CMOS

Note:

No connection for CMOS device inputs can be cause of malfunction. If no connection is provided to the input pins, it is possible that an internal input level may be generated due to noise, etc., hence causing malfunction. CMOS devices behave differently than Bipolar or NMOS devices. Input levels of CMOS devices must be fixed high or low by using a pull-up or pull-down circuitry. Each unused pin should be connected to V_{DD} or GND with a resistor, if it is considered to have a possibility of being an output pin. All handling related to the unused pins must be judged device by device and related specifications governing the devices.

③ STATUS BEFORE INITIALIZATION OF MOS DEVICES

Note:

Power-on does not necessarily define initial status of MOS device. Production process of MOS does not define the initial operation status of the device. Immediately after the power source is turned ON, the devices with reset function have not yet been initialized. Hence, power-on does not guarantee out-pin levels, I/O settings or contents of registers. Device is not initialized until the reset signal is received. Reset operation must be executed immediately after power-on for devices having reset function.

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Chapter 1 Overview

1.1 Introduction

This application note serves as an example of a PWM control for a universal motor, using an NEC K0 8-bit microcontroller.

The aim of the application note is to provide the user with an example for driving a universal motor via an IGBT directly from the mains, using a low-cost microcontroller.

A closed-loop control is realized by measuring the motor speed with a Hall sensor.

A suitable regulation algorithm depends largely on the final application and its requirements. Therefore the one implemented in this Application Note has to be seen just as an example.

The software and hardware configurations published here are examples and are not intended for mass production.

1.2 78K0 Family Overview

The heart of NEC`s 78K0 family is a powerful 8-bit CPU with an excellent power/performance ratio.

The 78K0 series is a highly integrated 8-bit single-chip microcontroller family.
It features CPU, ROM, RAM and peripheral functions such as A/D converter, UART, I^2C and serial interfaces as well as many dedicated ASSP peripheral functions.
All devices offer a range of on-chip memory options, both as Flash and Masked ROM.

The 78K0 core provides four register banks, each with 8-bit general registers that can be concatenated to form a 16-bit register, supporting 16-bit operations.
A total of 63 instructions are available. Bit manipulation operations are supported on all registers and the entire RAM address space.

Table 1-1: 78K0 Series, Differences between Subseries

Function		ROM Capacity	Timer				8-bit A/D	10-bit A/D	8-bit D/A	Serial Interface	I/O	V_{DD} MIN value	External expansion
Subseries Name			8-bit	16-bit	WT	WDT							
Controller	μPD78075B	32K to 40K	4 ch	1 ch	1 ch	1 ch	8 ch	-	2 ch	3 ch (UART: 1 ch)	88	1.8 V	×
	μPD78078	48K to 60K								3 ch (UART: 1 ch, I^2C: 1 ch)			
	μPD78078Y												
	μPD78070A	-								3 ch (UART: 1 ch)	61	2.7 V	
	μPD78070AY									3 ch (UART: 1 ch, I^2C: 1 ch)			
	μPD780058	24K to 60K	2 ch							3 ch (time-division UART: 1 ch)	68	1.8 V	
	μPD780058Y									3 ch (time-division UART: 1 ch, I^2C: 1 ch)			
	μPD780065	40K to 48K							-	4 ch (UART: 1 ch)	60	2.7 V	
	μPD780078	48K to 60K		2 ch			-	8 ch		4 ch (UART: 1 ch, I^2C: 1 ch)	52	1.8 V	
	μPD780078Y												
	μPD780034AS	8K to 32K		1 ch				4 ch		3 ch (UART: 1 ch, time-division 3-wire: 1 ch)	39		-
	μPD780034A							8 ch			51		×
	μPD780034AY						-	8 ch		3 ch (UART: 1 ch, I^2C: 1 ch)			
	μPD780024AY						8 ch	-					
On-chip power-on reset	78K0/KB1	8K to 24K	3 ch	1 ch	-	1 ch	-	4 ch	-	3 ch (UART: 2 ch)	22	2.7 V	-
	78K0/KC1	8K to 32K	4 ch		1 ch			8 ch			32		
	78K0/KD1										39		
	78K0/KE1	8K to 60K		2 ch						4 ch (UART: 2 ch)	22		
	78K0/KF1	24K to60K								5 ch (UART: 2 ch)	22		×

1.3 78K0 / KB1 Devices

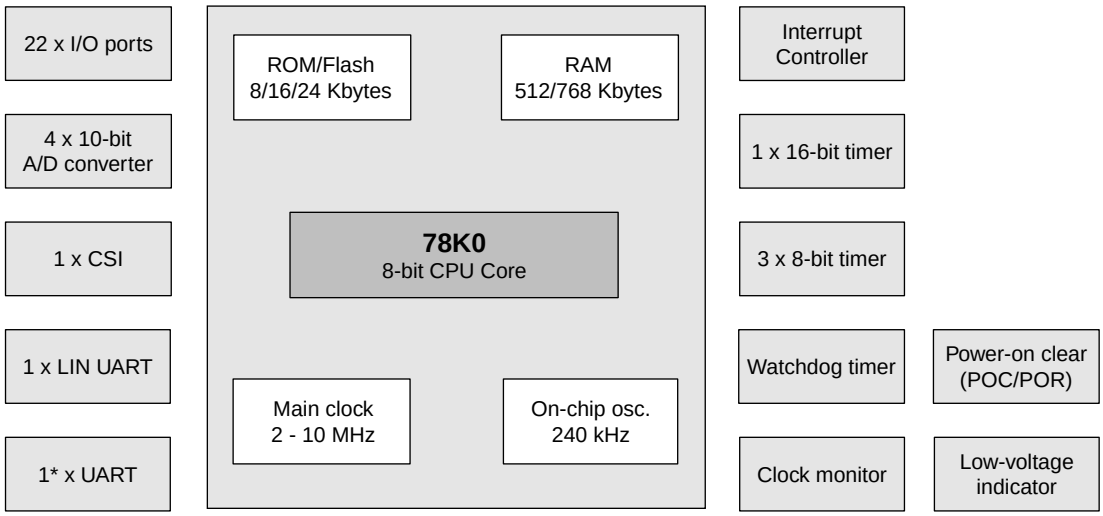
KB1 devices are part of the 78K0 microcontroller family.

With their many different integrated peripherals these devices are ideal for industrial and household appliances.

The KB1 series consists of four devices that differ mainly in RAM and ROM size.

For further details refer to the block diagram in Figure 1-1 and the feature list in section 1.4 “Feature List 78K0 / KB1” on page 12.

Figure 1-1: 78K0 / KB1 Block Diagram



Note: * - depending of the actual device

1.4 Feature List 78K0 / KB1

- 8-bit CISC CPU core
- Hardwired instructions for bit manipulation, multiplication and division
- 10 MHz max. clock frequency (200 ns min. instruction cycle time)
- On-chip oscillator
- Various memory configurations (including flash memory)
- Clock monitor
- Power-on clear (POC/POR) with $\overline{\text{RESET}}$ output
- Low-voltage indicator
- 4-channel A/D converter, 10-bit resolution
- Advanced UART (highly flexible, supports LIN by hardware)
- Standard UART (except µPD780101)
- 3-wire serial interface (CSI)
- 3 × 8-bit timers, 16-bit timer
- Watchdog timer
- 22 I/Os
- Operating voltage: 2.7 to 5.5 V
- Operating temperature: -40 to +125°C (device dependent)
- Package: 30-pin SSOP

Chapter 2 Universal Motor

2.1 Universal Motor

Universal motors are used in applications where speed control and high torque are required. Typical applications are in the field of white goods or power tools.

This motor can run on either DC or AC power, which is why it is called a universal motor.

The universal motor consists out of three main parts.

- Stator: contains the field windings to generate the radial magnetic flux
- Rotor: armature winding supplied with current via the carbon brushes to generate magnetic flux
- Brushes: mechanical linking of power supply and rotor windings

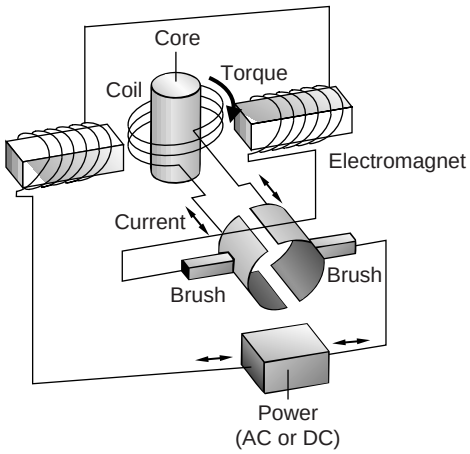
If a DC power is connected to a universal motor, the coils of the stator behave as if they were permanent magnets and the universal motor behaves like a DC motor, with one exception: it does not reverse direction when the current passing through it is reversed. It will continue to rotate in the same direction, because reversing the current through the rotor also reverses the current through the electromagnets. In effect, every pole of the motor changes from north to south or from south to north. As all the poles change their polarity, the motor will continue turning in the same direction.

As the universal motor always rotates in the same direction irrespective of the direction of the current, it works also when connected to AC power.

In order to change the motor's direction of rotation, the coils of the stator must be rewired, because this reverses the poles and thus the direction of rotation.

When running a universal motor on AC power, the motor experiences no torque during current reversal, but the average torque is sufficient to turn the motor as if it were connected to a DC power supply.

Figure 2-1: Universal Motor – Operation



2.2 Universal Motor Speed Control

One major requirement for electromotors used in domestic appliances is the ability to control its speed.

Two electronic solutions, phase angle control and chopper control, are widely used in industry today to realize speed control.
Both solutions have their strengths and weaknesses.

2.2.1 Phase Angle Control

Phase angle control is a simple and cost-effective solution to change the speed of a universal motor by using a triac.
The gate of the triac can be controlled directly by the output ports of a microcontroller and the whole circuitry is usually connected directly to the mains.

The advantages of this solution are:

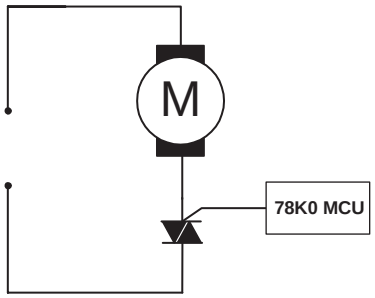
- simplicity
- cost effectiveness
- full speed control

On the other hand, the drawbacks are:

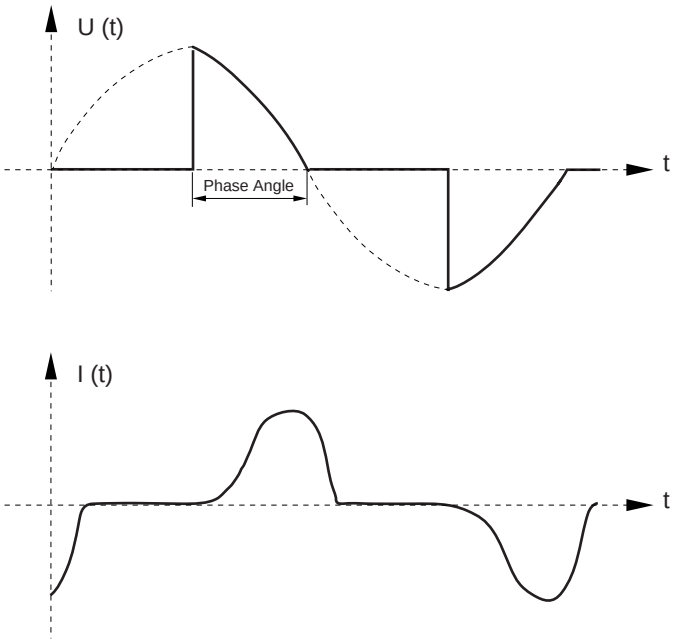
- high brush noise
- short lifetime
- high current ripple
- poor EMI behaviour

Figure 2-2: Phase Angle Control Principle

(a) Block Diagram



(b) Timing



2.2.2 Chopper Control

PWM control is another solution for controlling the speed of a universal motor.

The AC voltage from the mains is rectified and then switched at a high frequency by a Power MOSFET or an IGBT.

The switching frequency is usually in the range of 10 to 20 KHz.

PWM control is the more advanced solution for controlling the speed of a universal motor.
Driving a universal motor in PWM mode results in lower current ripple, which reduces the harmonics and therefore results in much better EMI behaviour.

The reduction of harmonics compared with phase angle control also reduces the copper and iron losses, which results in higher motor efficiency.

Running a motor in chopper mode also reduces acoustic noise, which is an important factor nowadays that should not be underestimated.

The advantages of this solution are:

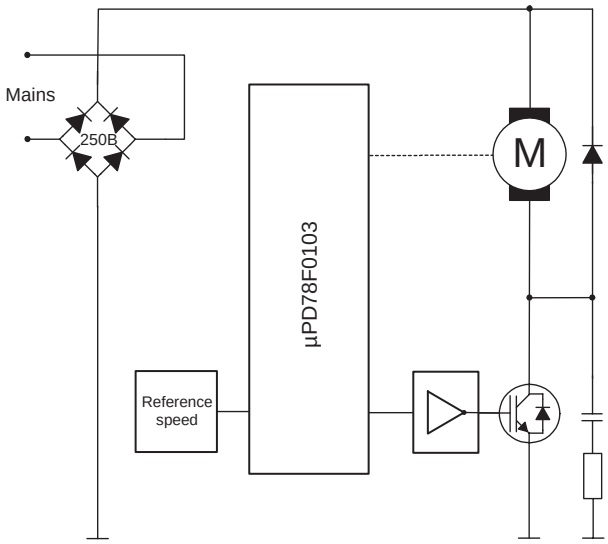
- higher motor efficiency
- lower acoustic noise
- smooth current behaviour

On the other hand, the drawbacks are:

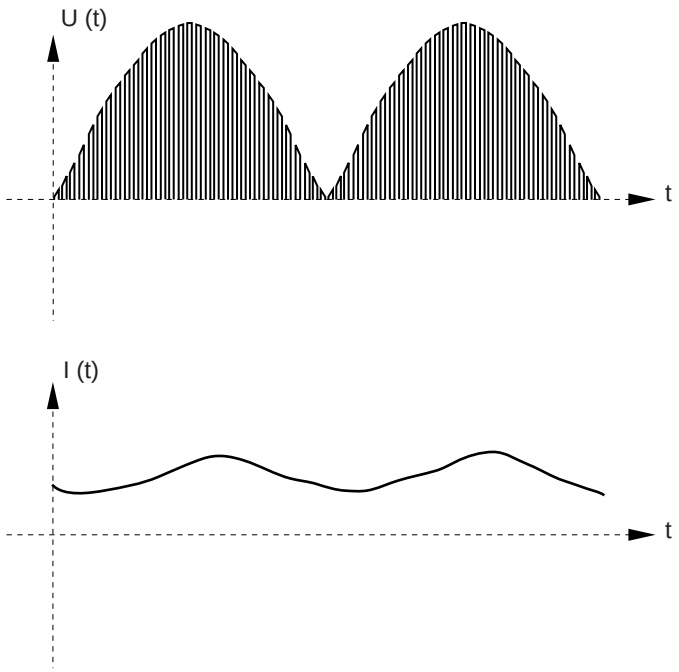
- more components needed
- price disadvantage
- filtering of chopper frequency required

Figure 2-3: Chopper Motor Control Principle

(a) Block Diagram



(b) Timing



[MEMO]

Chapter 3 System Design

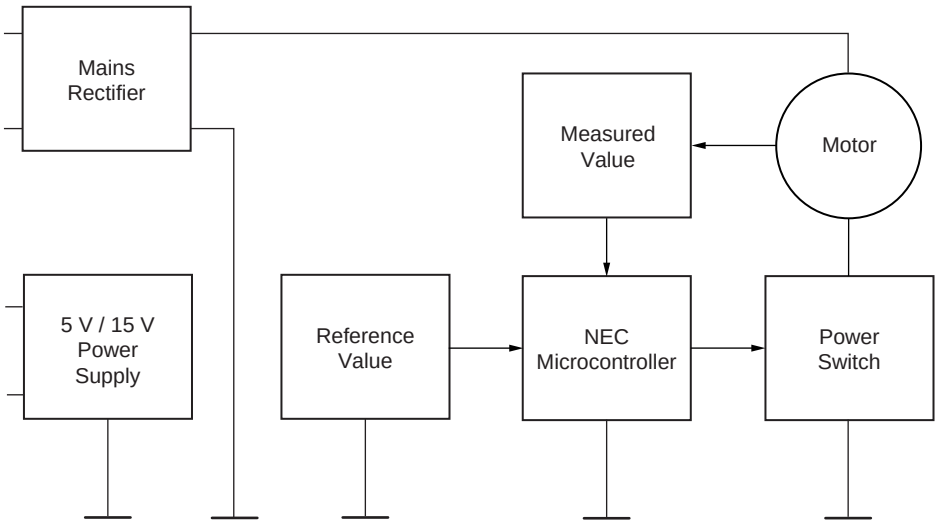
3.1 System Concept

The aim of this application note is to provide a speed regulation example realized by chopper control, using an 8-bit microcontroller from NEC`s 78K0 family.

The µPD78F0103 was selected for this application example.

The universal motor runs on rectified main voltage that is PWM-modulated.
An IGBT switches the rectified mains voltage via a suitable driver.
The PWM is generated by NEC's 8-bit microcontroller.
The motor speed can be controlled by changing the duty cycle of the generated PWM signal.
The motor speed is measured via a Hall sensor. A potentiometer, connected to the A/D converter of the microcontroller, delivers the reference value for the speed control function.
A closed-loop system is realized by comparing the reference and measured value.
Depending on the calculation results, the duty cycle of the PWM signal, controlling the power switch, is adapted to achieve a stable motor speed.

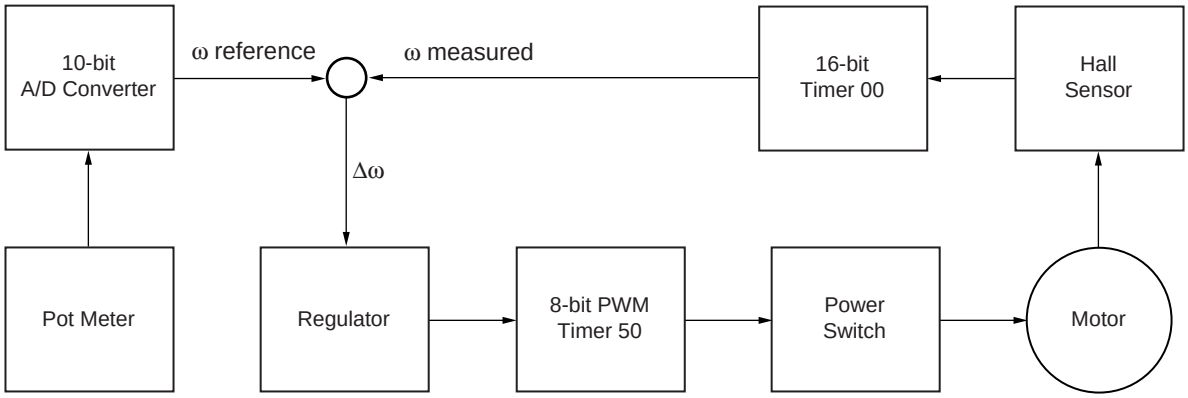
Figure 3-1: Chopper Control System Concept



3.2 System Configuration

The system configuration and the relationship between control software and hardware of the chopper controlled Universal Motor is shown in detail in Figure 3-2.

Figure 3-2: Chopper Control System Configuration



The motor speed information is given by the output signal of the Hall sensor. This signal is measured by the 16-bit timer/counter, operating in pulse-width measuring mode.

The reference value for the closed-loop control system is given by an analog potentiometer, connected to the on-chip A/D converter of the microcontroller.

The speed reference value is compared with measured value to generate the input signal to the regulator.

The output signal of the regulator itself changes the duty cycle of the 8-bit PWM counter in a way that constant motor speed is achieved.

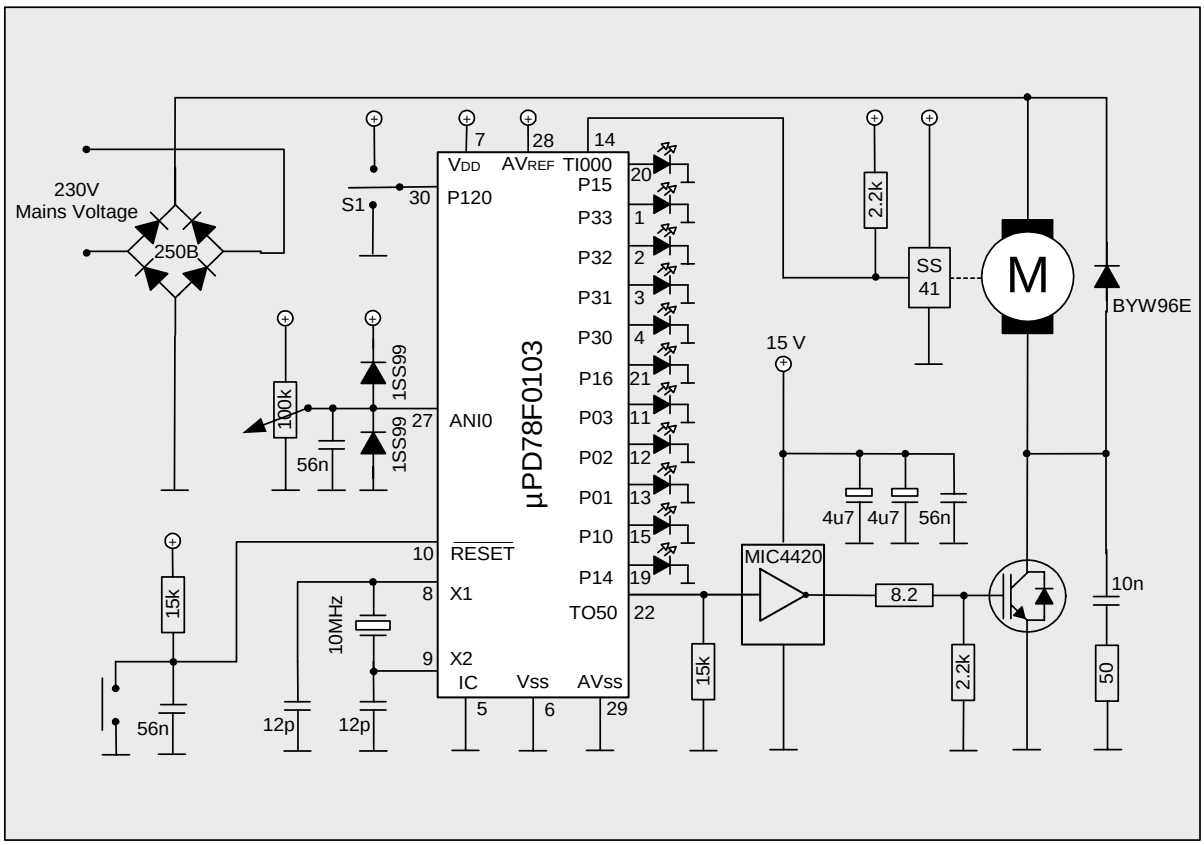
The function of each of the peripheral units is described in the next chapter.

Chapter 4 Hardware Configuration

4.1 Schematic Diagram

The diagram shows the chopper motor control design using a µPD78F0103 microcontroller.

Figure 4-1: Schematic Diagram



Switch S1 allows the selection between closed-loop and open-loop system operation.

4.2 Device Configuration

The configuration and operating environment of the µPD78F0103 is shown in Table 4-1.

Table 4-1: Device Configuration

Operating clock	10.00 MHz
Operating voltage	5 V
Internal ROM	24 KB
Internal RAM	768 Bytes

4.3 Peripherals and I/O Usage

Table 4-2 shows the microcontroller's I/O pins.
The pins used in the application and their functions are listed.

Table 4-2: I/O Configuration

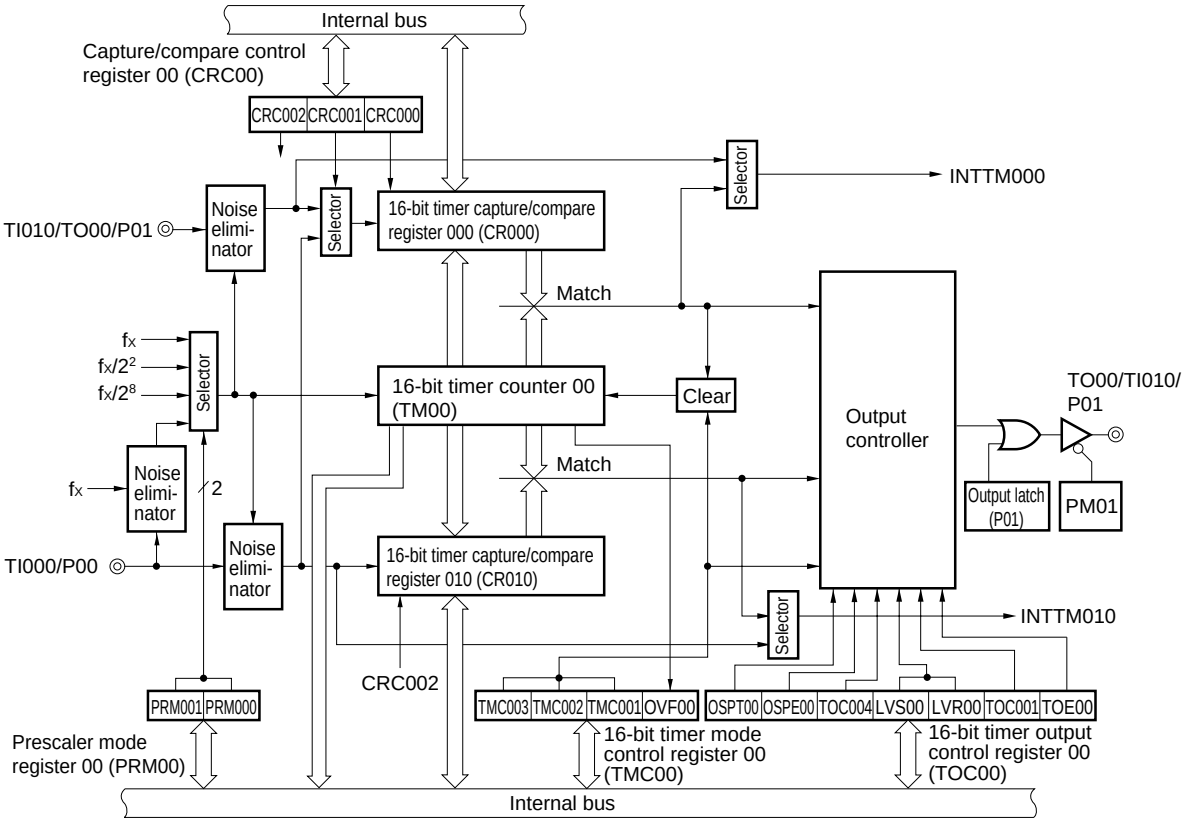
Pin No.:	Pin Name	Signal Name	Function
1	P33		LED
2	P32		LED
3	P31		LED
4	P30		LED
5	IC	V_{PP}	Programming
6	V_{SS}		Ground
7	V_{DD}		V_{DD}
8	X1		Main crystal
9	X2		Main crystal
10	$\overline{\text{RESET}}$		System reset
11	P03		LED
12	P02		LED
13	P01		LED
14	P00	TI000	Speed measure
15	P10		LED
16	P11		Not used
17	P12		Not used
18	P13		Not used
19	P14		LED
20	P15		LED
21	P16		LED
22	P17	TO50	PWM out
23	P130		Debugging
24	P23		Not used
25	P22		Not used
26	P21		Not used
27	P20	ANI0	Speed reference
28	AV_{REF}	5 V	A/D reference
29	AV_{SS}	0 V	Analog ground
30	P120	I/O	Switch

4.4 16-Bit Timer Function

As shown in Figure 3-2, “Chopper Control System Configuration,” on page 20, the 16-bit timer is used to measure the motor speed.
The 16-bit timer (TM00) of the µPD78K0103 has several operating modes:

- Interval timer
  - Generates interrupt request at the preset time interval
- PPG mode
  - Outputs a square wave, output pulse and frequency can be set
- Pulse width measurement
  - Measures pulse width of an external signal
- External event counter
  - Measures the number of external pulses
- Square wave output
  - Generates a square wave signal with an programmable frequency

Figure 4-2: 16-bit Timer/Event Counter 00 Block Diagram



The 16-bit timer is set to pulse width measurement mode to measure the frequency of the square wave signal.

A magnetic ring with eight pole pairs is mounted on the axis of the motor rotor.

The Hall sensor, mounted close to the magnetic ring, generates a square-wave signal.

The generated frequency of the Hall sensor is in the range of 300 Hz at low speed and increases to a maximum speed of 1800 Hz.
The count clock frequency of the 16-bit timer is programmable. In this application example, a frequency of 39 KHz is selected to measure the pulse width of the Hall sensor signal.

The pulse-width measurement is performed in a so-called “by means of restart” mode.
The speed measurement in this application example is not interrupt-controlled but performed in free-running mode.

The 16-bit timer is triggered by the rising edge of the Hall sensor signal.
A rising edge transfers the value of the 16-bit timer/counter to the CR010 capture/compare register and automatically clears and restarts TM00 for the next measurement.

This has the advantage that the last measured speed value is always available in CR010 and can be used at any time for the speed control algorithm.

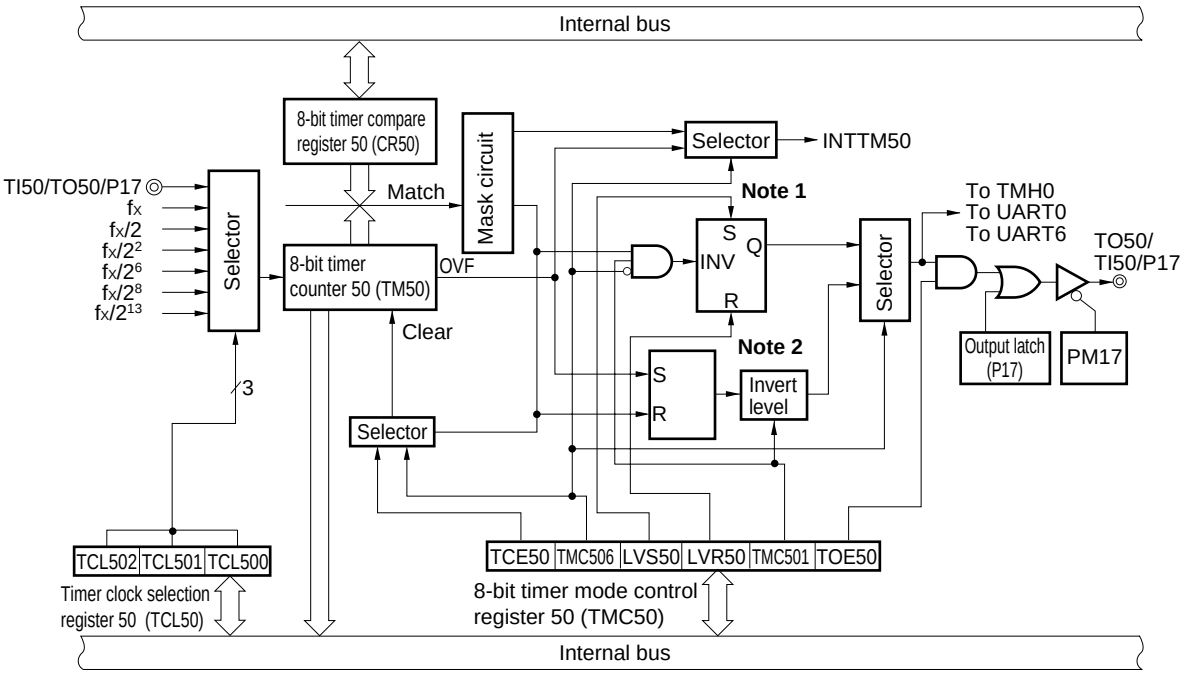
4.5 8 bit Timer / Event Counter 50

This timer is used to generate a PWM signal that controls the speed of the motor via the IGBT driver and IGBT. The PWM signal is varied by modifying the duty cycle.

The timer provides the following functions:

- interval timer
- external event counter
- square-wave output
- PWM output

Figure 4-3: 8-bit Timer/Event Counter 50 Block Diagram



Notes: 1. Timer output F/F

2. PWM output F/F

PWM output mode is selected and an output frequency of 10 KHz. The duty ratio of the 10 KHz signal is determined by the value of the 8-bit timer compare register 50 (CR50).

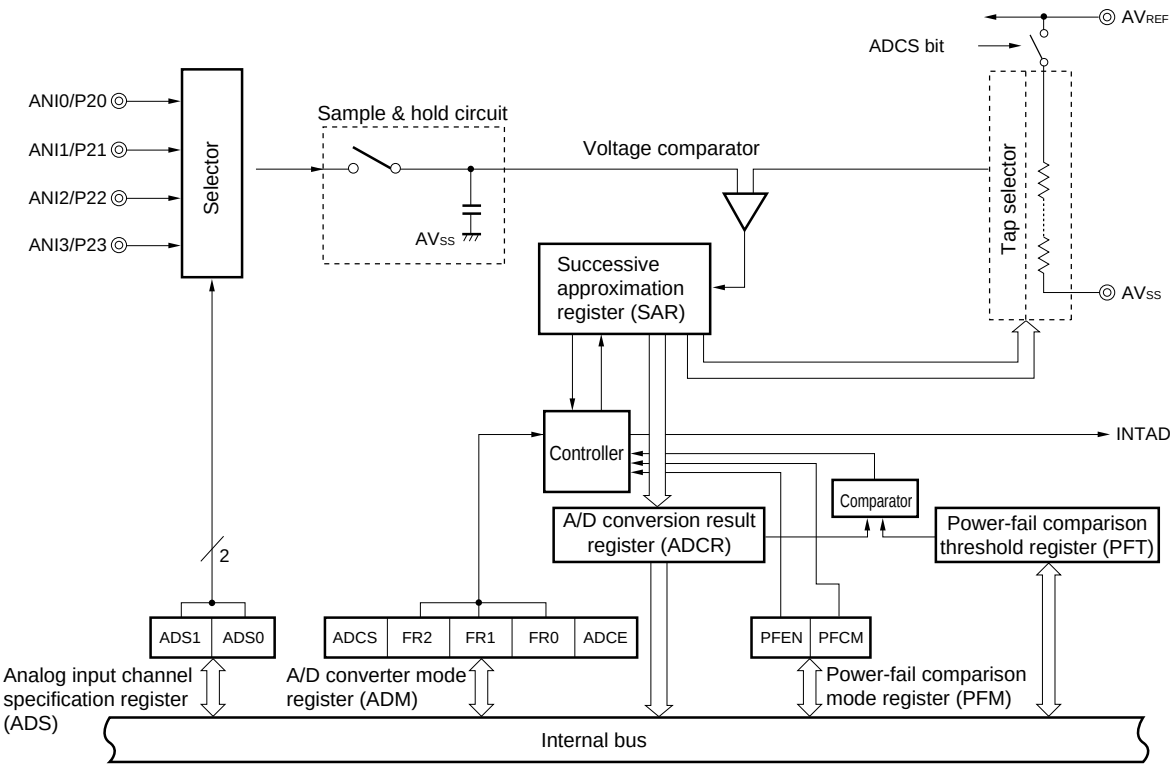
The calculation result of the speed control algorithm can be set on the fly, i.e., the CR50 register can be set at any time without stopping the PWM mode of the 8-bit timer.

A subroutine structure is used to modify the duty cycle by rewriting the CR50 register.

4.6 A/D Converter

The on-chip A/D converter has 4 input channels and a 10-bit resolution.

Figure 4-4: A/D Converter Block Diagram



In the example, channel one (ANI0) is connected to a potentiometer connected between V_{DD} and ground.
The A/D converted potentiometer value represents the reference value for the speed control algorithm for regulating the speed in the closed-loop system of this example.

The A/D conversion process is continuous and always the last converted value can be read out from the ADCR register of the µPD78F0103.

The conversion time of the µPD78F0103 is 28.8 µs.

Analog reference AV_{DD} and analog ground of the A/D converter are connected respectively to V_{DD} and V_{SS}.

[MEMO]

Chapter 5 Software Process Description

5.1 Main

The main program provides the framework within which the subroutines execute the various tasks of the closed-loop motor control application example.

The main program starts by initializing the stack pointer and device-specific IMS register settings, before invoking the global initialization subroutine called Micro.

The start-up routine performs a soft start-up of the universal motor until the reference speed is reached.

The endless loop of the main program consists of the PWM generation and the Display subroutine.

5.2 Micro

The Micro subroutine is responsible for initializing the system after a system reset.

It configures the basic clock settings of the device, selects the oscillators running the device during the different operating modes and initializes the used peripherals.
It has the following sections:

- Watchdog timer
- Initialization and switching of CPU clock
- Initialization of I/O ports
- A/D converter settings (reference value generation)
- PWM timer initialization (PWM generation)
- Timer 00 setting (speed measurement)

5.3 Start-up

This routine performs a soft start-up of the universal motor.

The A/D converter delivers the reference value of the motor speed.
After determining this value, the PWM register of Timer 50 is set to minimum speed.
Timer 50 generates the PWM signal for controlling the motor speed.

PWM generation of Timer 50 is enabled and the PWM register, containing the minimum speed value, is incremented to increase the motor speed until the reference speed is reached.

To achieve a soft start-up, a delay is executed after each change in the PWM duty cycle.

5.4 PWM control

This subroutine controls the motor speed.

In this application, controlling the motor speed means comparing reference and measured speed and calculating the speed error from the difference.
Speed error in this context means the motor is either running too fast, too slow or runs exactly at reference speed, in which case the speed error is zero.

Depending on the calculated speed error, the duty cycle of the generated PWM signal is modified by rewriting the CR50 register of Timer 50.

Modifying the PWM signal basically means incrementing or decrementing the corresponding variable (PWM_reference) in dependency on the calculated speed error.

The reference speed in this application is given by a potentiometer.
The A/D converter continuously converts its input value, i.e., approx. every 30 µs a new reference speed value is provided to the ADCR register for further calculations.
The A/D converter has a 10-bit resolution, which in this application is standardized to 8 bits.

The motor speed is measured with Timer 00 of the µPD78K0103.
Like the A/D converter, the speed measurement resolution is also standardized to 8 bits.

The timer runs in a so-called “pulse width measurement by means of restart” mode, i.e., the timer clears and starts its counter function automatically at the specified edges and provides the counter value for further calculation in its CR000 register.

A magnetic ring with eight pole pairs is mounted on the rotor of the universal motor.
A Hall sensor, mounted close to the ring provides speed information to Timer 00.

While calculating a new PWM duty cycle it is very important to check whether any underflow or overflow of the system limit values has been occurred.

‘Regulation delay’ is a function implemented in the PWM control subroutine. This is necessary to optimize the control performance of the whole system.

By changing the constants ‘regulation_delay_const_out’ and ‘regulation_delay_const_in’ this scheme can easily be adapted for transfer to other systems.

5.4.1 Open / Closed loop operation

This motor control application can run either in closed-loop or in open-loop mode.

The modes are selected via a switch connected to port P120.

In closed-loop operation the regulation algorithm as described above is performed.
In an open-loop system, this algorithm is switched off and basically the reference value provided in the ADCR register is transferred directly to the CR50 register of Timer 50, which specifies the duty cycle and thus the motor speed.

To achieve similar speeds in closed- and open-loop operation requires a conversion table with reference values.

The reason for that is in the different control characteristic curves in open- and closed-loop operation within this application.

5.5 Display

Display is a subroutine that in closed-loop operation indicates the regulation accuracy.
In open-loop mode the display is switched off.

The accuracy of the regulation is calculated from the reference and measured speed values.

11 LEDs indicate the regulation accuracy in 2% steps.
The green LED on port P16 indicates 100% accuracy. The red LEDs on ports P30, P31, P32, P33 and P01, P02, P03, P10 indicate the accuracy in 2% steps in positive and negative direction, respectively.

The yellow LEDs on port P15 and P14 indicate an accuracy of less than 8% in positive and negative direction, respectively.

5.6 Memory

These application example provides an approach to a basic chopper control system suitable for implementation with NEC's 78K0 8-bit Microcontroller family.

The memory requirements for these example are as follows:

- 78K0 – µPD78F0103

CODE memory	16 Kbytes available,	679 bytes used
DATA memory	768 bytes available	21 bytes used

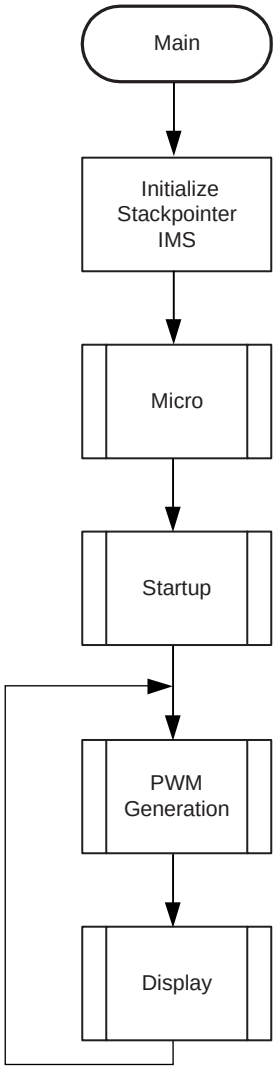
The 78K0 Microcontroller used for this application example provides further resources for additional user functions or/and adaptions to the regulation algorithm.

[MEMO]

Chapter 6 Flow Charts

6.1 Main Program

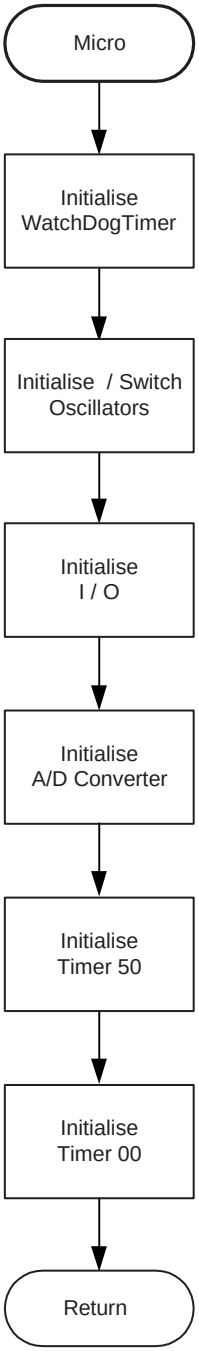
Figure 6-1: Main Program



6.2 Micro

This Module executes the initialisation of the microcontroller

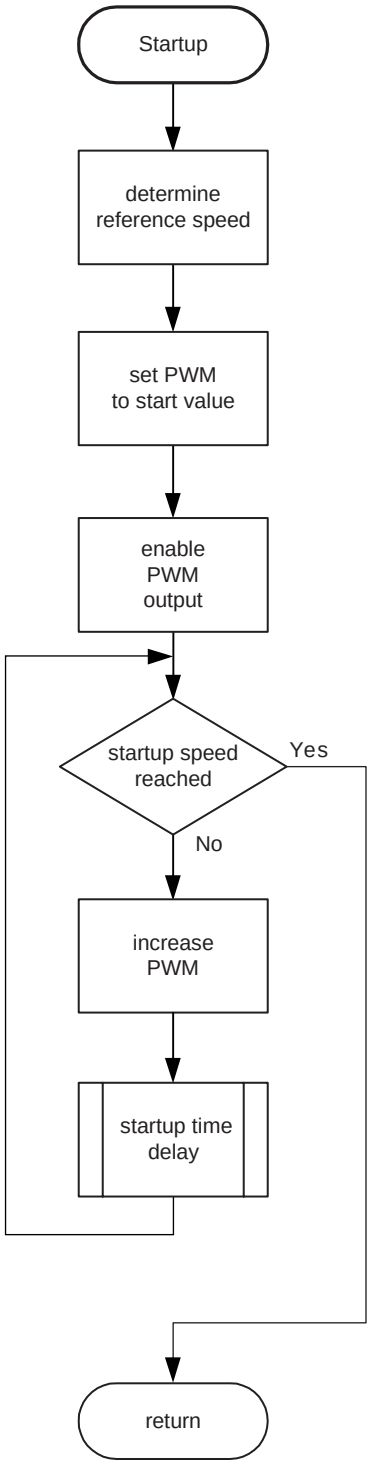
Figure 6-2: Initialisation of the Microcontroller



6.3 Start-up

This module performs soft start-up up to reference speed.

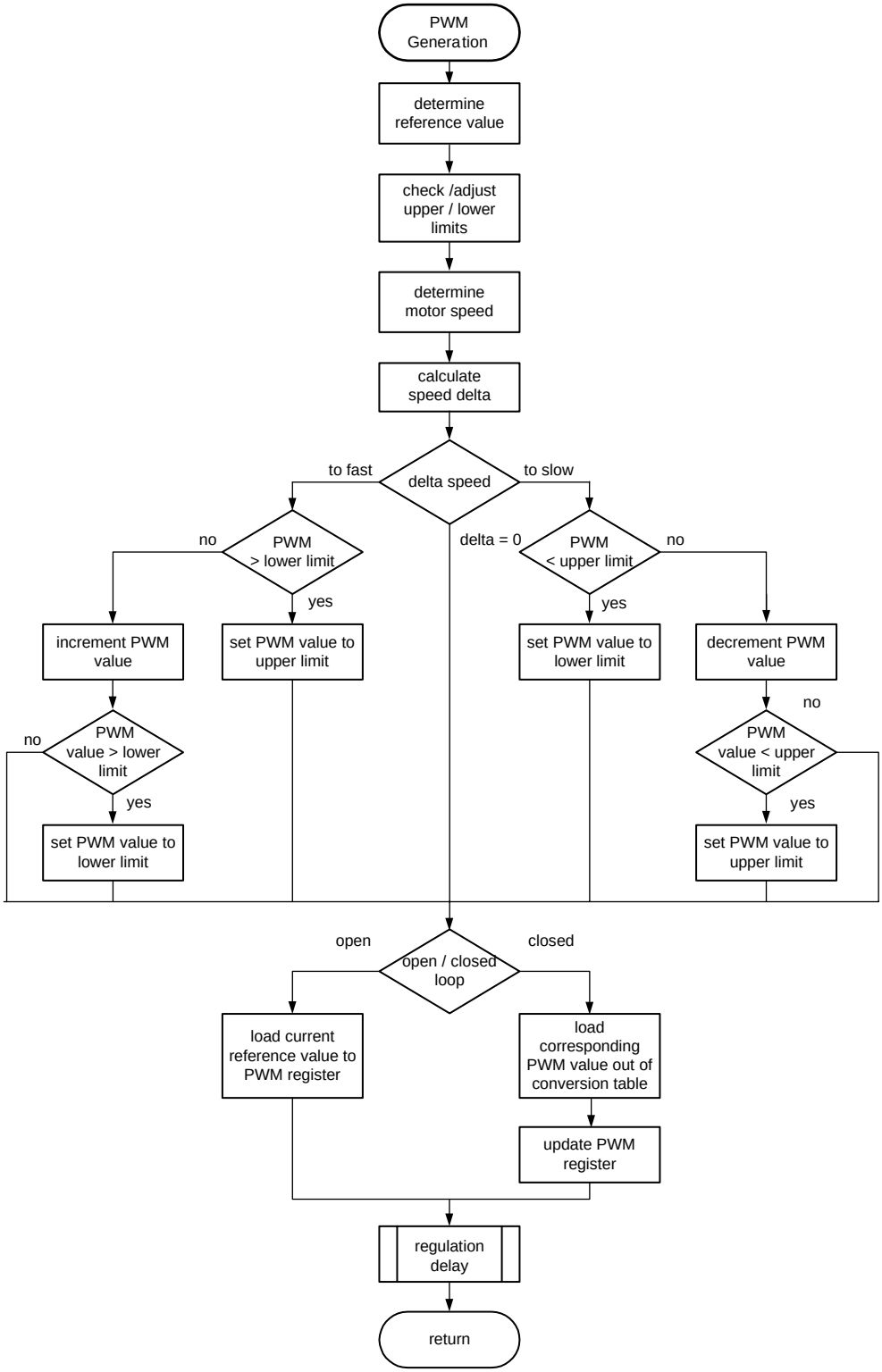
Figure 6-3: Start-up



6.4 PWM Generation

This module calculates out of reference and measured speed the new duty cycle of the PWM signal driving the Universal Motor.

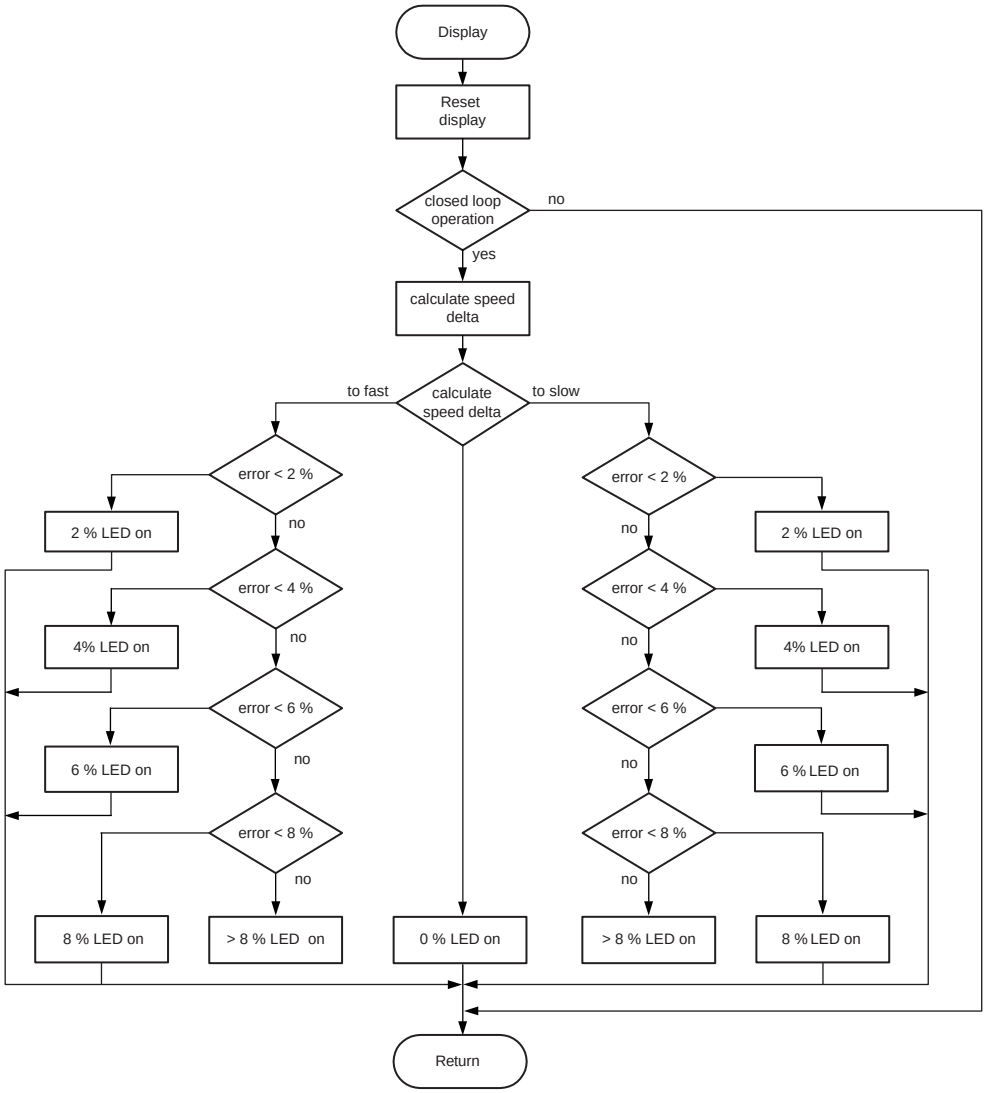
Figure 6-4: PWM Generation



6.5 Display

This module gives in 2% steps an indication on the achieved accuracy while running the application in closed loop mode.

Figure 6-5: Display



[MEMO]

Chapter 7 Program Listing

7.1 Main

```
/*****************************************************************************/
/*                                                                           */
/* File:        main.asm                                                     */
/* Project:     Motor Control ( chopper ) - startup                          */
/*                                                                           */
/* Description: Contains power-on reset initialisation and the idle loop.*/
/*                                                                           */
/* History:     031103  creation                                             */
/*                                                                           */
/*****************************************************************************/
; Enviroment    Device:     uPD78F0103
;               Assembler:  A78000      V3.21A/386
;               Compiler:   ICC78000    V3.21A/386
;               Linker:     XLINK       V4.51J/386
;===========================================================================
;Changes
;===========================================================================

    NAME    Main                    ; module name
;   P780103                         ; target device

#include   "df0103.h"                ; header file


                                    ;=====================================
                                    ; EXPORT LIST
                                    ;=====================================
                                    ; Constants:
                                    ; Variables:
                                    ; Flags:
                                    ; Labels:
    PUBLIC  Start                   ; reset entry address


                                    ;=====================================
                                    ; IMPORT LIST
                                    ;=====================================
                                    ; Constants:
                                    ; Variables:
                                    ; Flags:
                                    ; Labels:
    EXTERN  InitMicro               ;   from Micro
    EXTERN  Startup                 ;   from Startup
    EXTERN  loop                    ;   from PWM_generation
    EXTERN  Display                 ;   from Display


;---------------------------------------------------------------------------

            org     0000H
            dw      Start
```

```
;===============================================================================
; Segment name:  CODE
; Segment type:  relocatable code segment
; Address area:  internal ROM area
;===============================================================================
 RSEG            CODE
;===============================================================================


;===============================================================================
; Block type:       Program idle loop
; Purpose:          Initilisation
; Input:            none
; Output:           none
;===============================================================================

Start:      movw    AX,#0FE20h              ; set stackpointer
            movw    SP,AX
            mov     IMS,#06H
            di                              ; disable Interrupts
            call    InitMicro               ; switching ring -> main oscillator
            call    Startup

EndLess:    nop                             ; endless loop
            call    loop
            call    Display
            nop
            br      EndLess

            END
```

7.2 Micro

```
/*********************************************************************/
/*                                                                   */
/* File:        micro.asm                                            */
/* Project:     Motor Control ( chopper ) - startup                  */
/*                                                                   */
/* Description: Initilization of CPU and peripherals                 */
/*                                                                   */
/* History:     031103  creation                                     */
/*                                                                   */
/*********************************************************************/
; Enviroment    Device:     uPD78F0103
;               Assembler:  A78000      V3.21A/386
;               Compiler:   ICC78000    V3.21A/386
;               Linker:     XLINK       V4.51J/386
;====================================================================
;Changes
;====================================================================

    NAME    micro                   ; module name
    ;P780103                        ; target device

    #include"df0103.h"              ; header file

                                    ;=====================================
                                    ; EXPORT LIST
                                    ;=====================================
                                    ; Constants:
                                    ; Variables:
                                    ; Flags:
                                    ; Labels:
    PUBLIC  InitMicro               ; - module initilization

                                    ;=====================================
                                    ;IMPORT LIST
                                    ;=====================================
                                    ; Constants:
                                    ; Variables:
                                    ; Flags:
                                    ; Labels:

;====================================================================
; Segment name:  CODE
; Segment type:  relocatable code segment
; Address area:  internal ROM area
;====================================================================
 RSEG            CODE
;====================================================================


;====================================================================
; Block type:       global standard subroutine
; Purpose:          Initilization for chopper mode motor control
; Input:            none
; Output:           none
;====================================================================
```

```
InitMicro:  call    InitWDTM            ; Begin
            call    InitOsc             ;
            call    InitIO              ;
            call    InitAD              ;
            call    InitTM50            ;
            call    InitTM00            ;
            ret                         ; End

;=============================================================================
; Block type:       local standard subroutine
; Purpose:          Initilization / Switching of CPU clock
; Input:            none
; Output:           none
;=============================================================================

cPCCini     equ     00000000B           ; processor clock control register
                  ; ||||||||
                  ; ||||||||                PCCn    fCPU
                  ; ||||||||               --------------
                  ; |||||------------       000     fx
                  ; |||||                   001     fx/2
                  ; |||||                   010     fx/4
                  ; |||||                   011     fx/8
                  ; |||||                   100     fx/16
                  ; |||||
                  ; |||||                   other settings prohibited
                  ; |||||
                  ; ||||+---------------  fixed to 0
                  ; |||+----------------  fixed to 0
                  ; ||+-----------------  fixed to 0
                  ; |+------------------  fixed to 0
                  ; +-------------------  fixed to 0


cRCMini     equ     00000000B           ; Ring-Osc mode register
                  ; ||||||||
                  ; ||||||||                RSTOP
                  ; ||||||||               --------------
                  ; |||||||+------------   0       Ring-OSC working
                  ; |||||||               1       Ring-OSC stopped
                  ; |||||||
                  ; ||||||+-------------  fixed to 0
                  ; |||||+--------------  fixed to 0
                  ; ||||+---------------  fixed to 0
                  ; |||+----------------  fixed to 0
                  ; ||+-----------------  fixed to 0
                  ; |+------------------  fixed to 0
```

```
cMCMini     equ     00000000B           ; Main Clock Mode Register
                    ; ||||||||
                    ; |||||||+-----------  MCM0, [0] Ring-OSC input,[1] x1 input
                    ; ||||||+------------  MCS,  [0] Ring-OSC or [1] x1 working
                    ; |||||+-------------  fixed to 0
                    ; ||||+--------------  fixed to 0
                    ; |||+---------------  fixed to 0
                    ; ||+----------------  fixed to 0
                    ; |+-----------------  fixed to 0
                    ; +------------------  fixed to 0

cMOCini     equ     00000000B           ; Main Oscillator Control Register
                    ; ||||||||
                    ; |||||||+-----------  fixed to 0
                    ; ||||||+------------  fixed to 0
                    ; |||||+-------------  fixed to 0
                    ; ||||+--------------  fixed to 0
                    ; |||+---------------  fixed to 0
                    ; ||+----------------  fixed to 0
                    ; |+-----------------  fixed to 0
                    ; |
                    ; +------------------  MSTOP, [0] x1 osc, [1] x1 stopped

cOSTCini    equ     00000000B           ; Osc. Stab. Time Counter status reg.
                    ; ||||||||
                    ; ||||||||               MOSTn    t
                    ; ||||||||              --------------
                    ; |||++++------------    10000    204.8us
                    ; |||                   11000    819.2us
                    ; |||                   11100    1.64ms
                    ; |||                   11110    3.27ms
                    ; |||                   11111    6.55ms
                    ; |||
                    ; ||+----------------  fixed to 0
                    ; |+-----------------  fixed to 0
                    ; +------------------  fixed to 0

cOSTSini    equ     00000101B           ; Osc. Stab. Time Select register
                    ; ||||||||
                    ; ||||||||               OSTSn   t
                    ; ||||||||              --------------
                    ; |||||+++------------    001     204.8us
                    ; |||||                  010     819.2us
                    ; |||||                  011     1.64ms
                    ; |||||                  100     3.27ms
                    ; |||||                  101     6.55ms
                    ; |||||
                    ; |||||                  other settings prohibited
                    ; |||||
                    ; ||||+---------------  fixed to 0
                    ; |||+----------------  fixed to 0
                    ; ||+-----------------  fixed to 0
                    ; |+------------------  fixed to 0
                    ; +-------------------  fixed to 0
```

```
InitOsc:    mov     PCC,#cPCCini  ; fx=10MHz selectiert
            mov     RCM,#cRCMini  ; Ring-OSC working
            mov     MCM,#cMCMini  ; Ring-OSC supplied to CPU
            mov     MOC,#cMOCini  ; x1 working
            mov     OSTS,#cOSTSini; 6,5ms stabilization time selected

wait:       BF      OSTC.4,wait   ; check stabilization time
            set1    MCM.0         ; after stabilization time switch to x1

            ret                   ;


;=============================================================================
; Block type:       local standard subroutine
; Purpose:          Initilization Watchdogtimer
; Input:            none
; Output:           none
;=============================================================================

cWDTMini    equ     01111111B          ; Watchdog Timer Mode register
                  ; ||||||||
                  ; ||||||||                WDCSn   Ring-OSC    x1 OSC
                  ; ||||||||               ----------------------------
                  ; |||||-------------      000     8.53ms      819.2us
                  ; |||||                   001     17.07ms     1.64ms
                  ; |||||                   010     34.13ms     3.28ms
                  ; |||||                   011     68.27ms     6.55ms
                  ; |||||                   100     136.53ms    13.11ms
                  ; |||||                   101     273.07ms    26.21ms
                  ; |||||                   110     546.13ms    52.43ms
                  ; |||||                   111     1.09s       104.86ms
                  ; |||||
                  ; |||||                   WDCSn   clock selection
                  ; |||||                  -------------------------
                  ; |||---------------      00      fr Ring-OSC clock
                  ; |||                    01      fx Main Oscillator
                  ; |||                    1x      Watchdog timer stopped
                  ; |||
                  ; ||+-----------------  fixed to 1
                  ; |+------------------  fixed to 1
                  ; +-------------------  fixed to 0

InitWDTM    mov     WDTM,#cWDTMini      ; Watchdog timer stopped
            mov     IMS,#06H
            ret
```

```
;=======================================================================
; Block type:       local standard subroutine
; Purpose:          Initilization of I/O Ports
; Input:            none
; Output:           none
;=======================================================================

cPM0ini     equ     11110001B           ; Port Mode Register
                  ; ||||||||
                  ; |||||||+------------  PM00
                  ; ||||||+-------------  PM01
                  ; |||||+--------------  PM02
                  ; ||||+---------------  PM03
                  ; ++++----------------  unused, fixed to 1



cPM1ini     equ     00000000B           ; Port Mode Register
                  ; ||||||||
                  ; |||||||+------------  PM10
                  ; ||||||+-------------  PM11
                  ; |||||+--------------  PM12
                  ; ||||+---------------  PM13
                  ; |||+----------------  PM14
                  ; ||+-----------------  PM15
                  ; |+------------------  PM16
                  ; +-------------------  PM17



cPM3ini     equ     11110000B           ; Port Mode Register
                  ; ||||||||
                  ; |||||||+------------  PM30
                  ; ||||||+-------------  PM31
                  ; |||||+--------------  PM32
                  ; ||||+---------------  PM33
                  ; ++++----------------  unused, fixed to 1

cPM12ini    equ     11111110B           ; Port Mode Register
                  ; ||||||||
                  ; |||||||+------------  PM120
                  ; +++++++-------------  unused, fixed to 1


                                        ; PMxy [0] = output mode
                                        ; [1] = input mode

InitIO:     mov     PM0,#cPM0ini        ; Port output mode
            mov     PM1,#cPM1ini        ; Port output mode
            mov     PM3,#cPM3ini        ; Port output mode

            ret
```

```
;=======================================================================
; Block type:       local standard subroutine
; Purpose:          Initilization of A/D Converter
; Input:            none
; Output:           none
;=======================================================================

cADMini     equ     10000001B           ; A/D Converter Mode Register
                  ; ||||||||
                  ; |||||||+------------  ADCS, [0] stops conversion,
                  ;                          [1] enables conversion
                  ; ||||||+-------------  unused, fixed to 0
                  ; |||||+--------------  unused, fixed to 0
                  ; |||||
                  ; |||||                   FRn   Conversion time
                  ; |||||                  ----------------------
                  ; ||+++---------------    000     288/fx
                  ; ||                      001     240/fx
                  ; ||                      010     192/fx
                  ; ||                      010     144/fx
                  ; ||                      101     120/fx
                  ; ||                      110      96/fx
                  ; |+------------------  unused, fixed to 0
                  ; +-------------------  ADCE,ref.volt.gen.,[0] off,[1] on

cADSini     equ     00000000B ; Analog Input Channel Specification Register
                  ; ||||||||
                  ; ||||||||                ADSn     input channel
                  ; ||||||||                ----------------------
                  ; |||||+++------------    000      ANI0
                  ; |||||                   001      ANI1
                  ; |||||                   010      ANI2
                  ; |||||                   011      ANI3
                  ; |||||
                  ; |||||
                  ; ||||+---------------  unused, fixed to 0
                  ; |||+----------------  unused, fixed to 0
                  ; ||+-----------------  unused, fixed to 0
                  ; |+------------------  unused, fixed to 0
                  ; +-------------------  unused, fixed to 0


InitAD:     mov     ADM,#cADMini        ; start A/D Converter
            mov     ADS,#cADSini        ; select analog input channel ANI0

            ret
```

```
;=====================================================================
; Block type:       local standard subroutine
; Purpose:          Initilization of Timer 50 ( PWM out )
; Input:            none
; Output:           none
;=====================================================================

cTCL50ini   equ     00000100B           ; Timer Clock Selection Register 50
                  ; ||||||||
                  ; ||||||||                TCL50n  count clock selection
                  ; ||||||||               -------------------------------
                  ; |||||+++------------    000     TI50 fallinge edge
                  ; |||||                   001     TI50 rising edge
                  ; |||||                   010     10      MHz (fx)
                  ; |||||                   011     5       MHz
                  ; |||||                   100     2.5     MHz
                  ; |||||                   101     156.25  kHz
                  ; |||||                   110     39.06   kHz
                  ; |||||                   111     1.22    kHz
                  ; |||||
                  ; ||||+---------------  unused, fixed to 0
                  ; |||+----------------  unused, fixed to 0
                  ; ||+-----------------  unused, fixed to 0
                  ; |+------------------  unused, fixed to 0
                  ; +-------------------  unused, fixed to 0


cTMC50ini   equ     01000010B         ; format Timer Mode Control register
                  ; ||||||||
                  ; |||||||+-----------   TCE50, counter [0]stopped, [1]starts
                  ; ||||||+------------   TMC506, [0]clear & start, [1]PWM mode
                  ; ||||||
                  ; ||||||                LVS50  LVR50  Timer output F/F status
                  ; ||||||---------------------------------
                  ; ||||++--------------  0      0       no change
                  ; |||||                 0      1       output F/F reset (0)
                  ; |||||                 1      0       output F/F set (1)
                  ; |||||                 1      1       Setting prohibited
                  ; |||||
                  ; |||+----------------  unused, fixed to 0
                  ; ||+-----------------  unused, fixed to 0
                  ; |+------------------  TMC501, active,[0]high,[1]low
                  ; +-------------------  TOE50, output,[0]disabled,[1]enabled


;---------------------------------------------------------------------

InitTM50:   mov     TCL50,#cTCL50ini    ; count clock selection
            mov     TMC50,#cTMC50ini    ; select PWM mode, output enable

            ret
```

```
;=========================================================================
; Block type:       local standard subroutine
; Purpose:         Initilization of 16bit Timer 00 ( motor speed counter )
; Input:            none
; Output:           none
;=========================================================================
cTMC00ini   equ     00001010B           ; 16bit Timer Mode Control Register
                  ; ||||||||
                  ; |||||||+-----------; OVF00, Overflow detected,[0]no, [1]yes
                  ; |||||||
                  ; |||||||                  timer operating modes
                  ; |||||||               -------------------------------
                  ; ||||+++-------------    000     operating stop
                  ; |||||                   001     operating stop
                  ; |||||                   010     free running mode
                  ; |||||                   011     free running mode
                  ; |||||                   100     clear and start valid edge
                  ; |||||                   101     clear and start valid edge
                  ; |||||                   110     clear and start match TM/CR
                  ; |||||                   111     clear and start match TM/CR
                  ; |||||
                  ; |||+----------------  unused, fixed to 0
                  ; ||+-----------------  unused, fixed to 0
                  ; |+------------------  unused, fixed to 0
                  ; +-------------------  unused, fixed to 0

cCRC00ini   equ     00000111B           ; Capture/Compare Control Register
                  ; ||||||||
                  ; ||||||||              operating mode selection
                  ; |||||||+------------  CRC000, operates [0]compare [1]capture
                  ; |||||||
                  ; |||||||               capture trigger selection
                  ; ||||||+-------------  CRC000,capture [0]valid[1]reverse edge
                  ; ||||||
                  ; ||||||                operating mode selection
                  ; |||||+-------------- CRC010, operates [0]compare [1]capture
                  ; ||||+--------------- unused, fixed to 0
                  ; |||+---------------- unused, fixed to 0
                  ; ||+----------------- unused, fixed to 0
                  ; |+------------------ unused, fixed to 0
                  ; +------------------- unused, fixed to 0

cTOC00ini   equ     00000001B           ;16-bit Timer Output Control Register
                  ; ||||||||
                  ; |||||||+------------ TOE00, [0] disables, [1] enables outp
                  ; ||||||+------------- TOC001,[0] disables [1] enables inv
                  ; ||||||
                  ; ||||||                LVS00  LVR00  Timer output F/F status
                  ; ||||||                ---------------------------------
                  ; ||||++-------------- 0      0       no change
                  ; ||||                 0      1       Timer output F/F
                  ; ||||                 1      0       Timer output F/F set
                  ; ||||                 1      1       Setting prohibited
                  ; ||||
                  ; |||+---------------- TOC004, [0]disables,[1]enables inv. op
                  ; ||+----------------- unused, fixed to 0
                  ; |+------------------ unused, fixed to 0
                  ; +------------------- unused, fixed to 0
```

```
cPRM00ini   equ     00010010B           ;Prescaler Mode Register 00
                  ; ||||||||
                  ; ||||||||             PRM001  PRM000 count clock selection
                  ; ||||||||             ---------------------------------
                  ; ||||||++------------ 0      0       fx (10MHz)
                  ; ||||||               0      1       fx/4 (2.5MHz)
                  ; ||||||               1      0       fx/256 (39.06kHz)
                  ; ||||||               1      1       TI000 valid edge
                  ; ||||||
                  ; |||||+--------------  unused, fixed to 0
                  ; ||||+---------------  unused, fixed to 0
                  ; ||||
                  ; ||||                  ES001  ES000  TI000 valid edge select
                  ; ||||                  ---------------------------------
                  ; ||++---------------- 0      0       falling edge
                  ; ||                   0      1       rising edge
                  ; ||                   1      0       setting prohibites
                  ; ||                   1      1       both edges
                  ; ||
                  ; ||                   ES101  ES100  TI010 valid edge select
                  ; ||                   ---------------------------------
                  ; ++------------------ 0      0       no change
                  ;                      0      1       Timer output F/F
                  ;                      1      0       Timer output F/F set
                  ;                      1      1       Setting prohibited


;-------------------------------------------------------------------------

InitTM00:   mov     TMC00,#cTMC00ini    ; count clock selection
            mov     CRC00,#cCRC00ini    ; select PWM mode, output enable
            mov     TOC00,#cTOC00ini
            mov     PRM00,#cPRM00ini

            ret

            END
```

7.3 Start-up

```
/*****************************************************************************/
/*                                                                           */
/* File:        Startup.asm                                                  */
/* Project:     Motor Control ( chopper ) - start-up                         */
/*                                                                           */
/* Description: Contains power-on reset initialisation and the idle loop.*/
/*                                                                           */
/* History:     031103  creation                                             */
/*                                                                           */
/*****************************************************************************/
; Enviroment    Device:     uPD78F0103
;               Assembler:  A78000      V3.21A/386
;               Compiler:   ICC78000    V3.21A/386
;               Linker:     XLINK       V4.51J/386
;===========================================================================
;Changes
;===========================================================================

  NAME          Startup           ; module name
; P780103                        ; target device

#include        "df0103.h"        ; header file


                                  ;=====================================
                                  ; EXPORT LIST
                                  ;=====================================
                                  ; Constants:
                                  ; Variables:
                                  ; Flags:
                                  ; Labels:
  PUBLIC        Startup


                                  ;=====================================
                                  ;IMPORT LIST
                                  ;=====================================
                                  ; Constants:
                                  ; Variables:
                                  ; Flags:
                                  ; Labels:
```

```
;=======================================================================
; Segment name:  UDATA0
; Segment type:  relocatable data segment
; Address area:  short address RAM area
;=======================================================================
 RSEG      UDATA0  (1)             ; (1) segment starts at even address
 SADDR
;=======================================================================

EVEN
startup_delay_in            DS    2
startup_delay_out           DS    1
startup_reference_v         DS    1
startup_measured_v          DS    1


;=======================================================================
; Block type:       Standard Subprogram
; Purpose:          Startup
; Input:            none
; Output:           none
;=======================================================================
 RSEG               CODE
;-----------------------------------------------------------------------

Startup:    movw    AX,ADCR                ; AD , speed reference value
            mov     startup_reference_v,A  ; store speed reference value
            mov     A,#0C0H                ; PWM start value (lower limit)
            set1    TCE50                  ; count operation start
            set1    TOE50                  ; output enable
cont_startup:mov    CR50,A                 ; set with decremented PWM value
            cmp     A,startup_reference_v  ; check startup stop value
            bz      retur                  ; if PWM=reference leave startup
            dec     A
            call    startup_delay          ; startup delay time constant
            mov     B,A
            movw    AX,ADCR                ; AD , speed reference value
            mov     startup_reference_v,A  ; store speed reference value
            mov     A,B
            br      cont_startup

retur:              ret
```

```
;=======================================================================
; Block type:       Standard Subroutine
; Purpose:          Startup Regulation Timing
; Input:            none
; Output:           none
;=======================================================================

startup_delay: push   AX
               mov    startup_delay_out,#060H
loop_out:      nop
               movw   startup_delay_in,#6000H
loop_in:       dec    startup_delay_in
               nop
               BNZ    loop_in
               dec    startup_delay_out
               BNZ    loop_out
               pop    AX
               ret

               END
```

7.4 PWM Generation

```
/*********************************************************************/
/*                                                                   */
/* File:        PWM_Control.s26                                      */
/* Project:     Motor Control ( chopper ) - startup                  */
/*                                                                   */
/* Description: Single phase Motor with chopper control              */
/*           This software example provides a basic PWM control algorithm */
/*           for Universal Motor control. Timer_50 is used to generate a */
/*           10kHz PWM signal. This PWM signal is switching via an IGBT  */
/*           the rectified line voltage and therewith the speed of the   */
/*           Universal Motor. Via a switch, it can be selected whether   */
/*           the system runs in closed or open loop mode.                */
/*           The speed can be controlled by a potmeter, connected to the */
/*           microcontrollers 5V Vdd. The adjusted DC level is           */
/*          AD converted and therewith giving the reference speed value */
/*           A magnetic ring with eight pol pairs is mounted on the motor*/
/*           rotor axis to measure the speed.                        */
/*                                                                   */
/*********************************************************************/
/*                                                                   */
/* History:     031103  creation                                     */
/*                                                                   */
/*********************************************************************/
; Enviroment    Device:     uPD78F0103
;               Assembler:  A78000      V3.21A/386
;               Compiler:   ICC78000    V3.21A/386
;               Linker:     XLINK       V4.51J/386
;====================================================================
;Changes
;====================================================================

  NAME          PWM_Control       ; module name
; P780103                         ; target device

                                  ;=====================================
                                  ; EXPORT LIST
                                  ;=====================================
                                  ; Constants:
                                  ; Variables:
                                  ; Flags:
                                  ; Labels:
    PUBLIC      loop
    PUBLIC      speed_reference_value
    PUBLIC      speed_measured_value
    PUBLIC      PWM_reference
    PUBLIC      Monitor_ADCR
    PUBLIC      Monitor_CR010
    PUBLIC      Monitor_A
    PUBLIC      Monitor_CR50
    PUBLIC      speed_delta
```

```
                                    ;====================================
                                    ; IMPORT LIST
                                    ;====================================
                                    ; Constants:
                                    ; Variables:
                                    ; Flags:
                                    ; Labels:
    EXTERN      Table               ; from Table

;===============================================================================
; INCLUDE FILE LIST
;===============================================================================

#include        "df0103.h"              ; header file
 LSTOUT-
 $df0103.h
 LSTOUT+
 COL 132

;===============================================================================
; Segment name:  UDATA0
; Segment type:  relocatable data segment
; Address area:  short address RAM area
;===============================================================================
 RSEG      UDATA0  (1)                 ; (1) segment starts even address
 SADDR
;===============================================================================
                                                        ; Global:

                            EVEN
Monitor_CR010               DS      2
Monitor_ADCR                DS      2
Monitor_CR50                DS      1
Monitor_A                   DS      1
speed_reference_value       DS      1
speed_measured_value        DS      1
PWM_reference               DS      1
speed_delta                 DS      1
                            EVEN
regulation_delay_const_in   DS      2
startup_delay_in            DS      2
regulation_delay_const_out  DS      1
startup_delay_out           DS      1


;===============================================================================
 RSEG          Data                      ; segment starts at even address
 SADDR
;===============================================================================
; empty
```

```
;=============================================================================
; Segment name:  BITVARS
; Segment type:  relocatable bit segment
; Address area:  short address RAM area
;=============================================================================
 RSEG            BITVARS                 ; segment starts at even address
 SADDR
;=============================================================================
; empty



;=============================================================================
; Segment name:  INTVEC
; Segment type:  interrupt vector
; Address area:  ROM, 0x0000...0x003f
;=============================================================================
  COMMON    INTVEC          ; should be located at 0000H in *.xcl file
;=============================================================================
; empty

;=============================================================================
; Segment name:  CODE
; Segment type:  relocatable code segment
; Address area:  internal ROM area
;=============================================================================
 RSEG            CODE
;=============================================================================

;=============================================================================
; Block type:    Standard Subroutine
; Purpose:       startup and closed loop regulation
; Input:         none
; Output:        none
;=============================================================================

loop:
reference_speed:   movw    AX,ADC              ; capture speed ref. value
                   movw    Monitor_ADCR,AX     ; ( watch function )
                   cmp     A,#015H
                   BC      set_to_USL          ; set to Upper Speed Limit
                   cmp     A,#080H
                   BNC     set_to_LSL          ; set to Lower Speed Limit
                   mov     speed_reference_value,A ; store speed ref. value
                   BR      measured_speed
set_to_USL:        mov     speed_reference_value,#015H
                   BR      measured_speed
set_to_LSL:        mov     speed_reference_value,#080H

measured_speed:    movw    AX,CR010            ; mov measured speed to AX
                   movw    Monitor_CR010,AX    ; help word ( watch function )

                   xch     A,X
                   mov     speed_measured_value,A  ; speed measured value

delta_speed:       sub     A,speed_reference_value
                   mov     speed_delta,A       ; speed difference
                   bz      speed_stable        ; delta=0, speed ok go to stable
```

```
                bnc     speed_to_slow       ; C=1 means speed to high

speed_to_high:  cmp     PWM_reference,#0C0H; check lower speed limit
                bc      increment           ; if no, increment PWM value
                mov     A,#0C0H             ; if yes, set lower speed limit
                mov     PWM_reference,A
                br      set_new_PWM

increment:      inc     PWM_reference       ; inc PWM ref => decrease speed
                inc     PWM_reference
                inc     PWM_reference
            cmp     PWM_reference,#0C0H ; check lower speed limit
            bc      set_new_PWM         ;
            mov     A,#0C0H             ; reset low. limit if overflow
            mov     PWM_reference,A
            br      set_new_PWM

speed_to_slow: cmp  PWM_reference,#020H; check if PWM below upper limit
            bnc     decrement           ; if yes decrement PWM value
            mov     A,#020H             ; if yes, set PWM to upper limit
            mov     PWM_reference,A
            br      set_new_PWM

decrement:  dec     PWM_reference       ; dec PWM ref => increase speed
            dec     PWM_reference
            dec     PWM_reference
            cmp     PWM_reference,#020H ; check upper speed limit
            bnc     set_new_PWM
            mov     A,#020H             ; reset up. limit if underflow
            mov     PWM_reference,A

set_new_PWM: mov    A,PWM_reference
            BT      P12.0,c_loop        ; sel closed/open loop operation
            mov     A,speed_reference_value
            mov     B,A                 ; speed ref to B for Table calc.
            movw    HL,#Table
            mov     A,[HL+B]            ; mov corresponding PWM to A

            mov     P13,#1              ; generation of reference pulse
            nop
            mov     P13,#0

c_loop:     mov     CR50,A              ; set new PWM_value
            mov     Monitor_CR50,A      ; help register ( watch func. )
            mov     PWM_reference,A     ; store new PWM_value
speed_stable: call  regulation_delay    ; regulation time constant

            ret
```

```
;=========================================================================
; Block type:     Standard Subroutine
; Purpose:        Adjustment Regulation Timing
; Input:          none
; Output:         none
;=========================================================================
regulation_delay:  mov regulation_delay_const_out,#01H; 02 0080 = 330usec
loop_reg_out:      nop
                   movwregulation_delay_const_in,#0040H
loop_reg_in:       dec regulation_delay_const_in
                   nop
                   BNZ loop_reg_in
                   dec regulation_delay_const_out
                   BNZ loop_reg_out
                   ret
                   END

;   Note: setting 15-01-04 01_0040_upper 040_6000_lower
```

7.5 Display

```
/*****************************************************************************/
/*                                                                           */
/* File:        display.asm                                                  */
/* Project:     Motor Control ( chopper ) - startup                          */
/*                                                                           */
/* Description: Contains power-on reset initialisation and the idle loop.*/
/*                                                                           */
/* History:     031103  creation                                             */
/*                                                                           */
/*****************************************************************************/
; Enviroment    Device:     uPD78F0103
;               Assembler:  A78000      V3.21A/386
;               Compiler:   ICC78000    V3.21A/386
;               Linker:     XLINK       V4.51J/386
;===========================================================================
;Changes
;===========================================================================

  NAME          Display           ; module name
; P780103                        ; target device

#include        "df0103.h"        ; header file


                                  ;=====================================
                                  ; EXPORT LIST
                                  ;=====================================
                                  ; Constants:
                                  ; Variables:
                                  ; Flags:
                                  ; Labels:
   PUBLIC        Display


                                  ;=====================================
                                  ; IMPORT LIST
                                  ;=====================================
                                  ; Constants:
  EXTERN        speed_measured_value; Variables:
  EXTERN        speed_reference_value
                                  ; Flags:
                                  ; Labels:
  EXTERN        PWM_generation    ;   from .......
  EXTERN        InitMicro         ;   from Micro
  EXTERN        loop              ;   from PWM_generation

;===========================================================================
; Segment name:  CODE
; Segment type:  relocatable code segment
; Address area:  internal ROM area
;===========================================================================
 RSEG            CODE
;===========================================================================
```

```
;=======================================================================
; Block type:       Subprogram
; Purpose:          Display speed error
; Input:            none
; Output:           none
;=======================================================================
Display:                      ; clear ports

            mov   P3,#00H
            clr1  P0.1
            clr1  P0.2
            clr1  P0.3
            clr1  P1.0
            clr1  P1.6
            clr1  P1.5
            clr1  P1.4

            BF    P12.0,skip   ; check open / closed loop

            mov   A,speed_measured_value  ; caculate speed difference
            sub   A,speed_reference_value
            bz    GreenLED
            bnc   to_slow

to_fast:    cmp   A,#0F9H                 ; select accuracy LED
            bnc   LEDP03
            cmp   A,#0F3H
            bnc   LEDP02
            cmp   A,#0EDH
            bnc   LEDP01
            cmp   A,#0E7H
            bnc   LEDP10
            br    Y_fast


to_slow:    cmp   A,#07H                  ; select accuracy LED
            bc    LEDP30
            cmp   A,#0DH
            bc    LEDP31
            cmp   A,#013H
            bc    LEDP32
            cmp   A,#019H
            bc    LEDP33
            br    Y_slow


Y_slow:     set1  P1.5                    ; accuracy >  8%
            ret
Y_fast:     set1  P1.4                    ; accuracy > 8%
            ret
GreenLED:   set1  P1.6
            ret
LEDP30      set1  P3.0
            ret
LEDP31      set1  P3.1
            ret
LEDP32      set1  P3.2
            ret
```

```
LEDP33      set1  P3.3
            ret
LEDP03      set1  P0.3
            ret
LEDP02      set1  P0.2
            ret
LEDP01      set1  P0.1
            ret
LEDP10      set1  P1.0
skip        ret

            END
```

7.6 Conversion Table

```
; Motor Control
; Table
; Conversion Table to adapt Motor speed in open / closed loop operation

 PUBLIC                Table

 RSEG       CONST
 saddr

Table:
;AD 00h
        DB   018H       ; AD_00
        DB   018H       ; AD_01
        DB   018H       ; AD_05
        DB   018H       ; AD_05
        DB   018H       ; AD_05
        DB   018H       ; AD_05
        DB   018H       ; AD_06
        DB   018H       ; AD_07
        DB   018H       ; AD_08
        DB   018H       ; AD_09
        DB   018H       ; AD_0A
        DB   018H       ; AD_0B
        DB   018H       ; AD_0C
        DB   018H       ; AD_0B
        DB   018H       ; AD_0E
        DB   018H       ; AD_0F
;AD 10h
        DB   018H       ; AD_10
        DB   019H       ; AD_11
        DB   019H       ; AD_15
        DB   020H       ; AD_15
        DB   020H       ; AD_15
        DB   022H       ; AD_15
        DB   028H       ; AD_16
        DB   02BH       ; AD_17
        DB   030H       ; AD_18
        DB   035H       ; AD_19
        DB   03CH       ; AD_1A
        DB   045H       ; AD_1B
        DB   050H       ; AD_1C
        DB   058H       ; AD_1B
        DB   05EH       ; AD_1E
        DB   064H       ; AD_1F

;AD 20h
        DB   064H       ; AD_20
        DB   066H       ; AD_21
        DB   068H       ; AD_22
        DB   069H       ; AD_23
        DB   070H       ; AD_24
        DB   072H       ; AD_25
        DB   073H       ; AD_26
        DB   074H       ; AD_27
        DB   075H       ; AD_28
```

```
        DB   076H       ; AD_29
        DB   077H       ; AD_2A
        DB   078H       ; AD_2B
        DB   080H       ; AD_2C
        DB   082H       ; AD_2B
        DB   084H       ; AD_2E
        DB   085H       ; AD_2F

;AD 30h
        DB   085H       ; AD_30
        DB   086H       ; AD_31
        DB   087H       ; AD_33
        DB   088H       ; AD_33
        DB   089H       ; AD_33
        DB   089H       ; AD_33
        DB   08AH       ; AD_36
        DB   08AH       ; AD_37
        DB   08BH       ; AD_38
        DB   08CH       ; AD_39
        DB   08DH       ; AD_3A
        DB   08EH       ; AD_3B
        DB   090H       ; AD_3C
        DB   092H       ; AD_3B
        DB   094H       ; AD_3E
        DB   096H       ; AD_3F

;AD 40h
        DB   096H       ; AD_40
        DB   097H       ; AD_41
        DB   098H       ; AD_43
        DB   099H       ; AD_43
        DB   09AH       ; AD_44
        DB   09AH       ; AD_45
        DB   09AH       ; AD_46
        DB   09BH       ; AD_47
        DB   09BH       ; AD_48
        DB   09BH       ; AD_49
        DB   09CH       ; AD_4A
        DB   09CH       ; AD_4B
        DB   09CH       ; AD_4C
        DB   09DH       ; AD_4B
        DB   09EH       ; AD_4E
        DB   0A0H       ; AD_4F

;AD 50h
        DB   0A0H       ; AD_50
        DB   0A1H       ; AD_51
        DB   0A1H       ; AD_55
        DB   0A2H       ; AD_55
        DB   0A2H       ; AD_55
        DB   0A2H       ; AD_55
        DB   0A3H       ; AD_56
        DB   0A3H       ; AD_57
        DB   0A4H       ; AD_58
        DB   0A4H       ; AD_59
        DB   0A5H       ; AD_5A
        DB   0A6H       ; AD_5B
        DB   0A7H       ; AD_5C
```

```
        DB    0A7H      ; AD_5B
        DB    0A8H      ; AD_5E
        DB    0A8H      ; AD_5F

;AD 60h
        DB    0A8H      ; AD_60
        DB    0A8H      ; AD_61
        DB    0A8H      ; AD_62
        DB    0A9H      ; AD_63
        DB    0A9H      ; AD_64
        DB    0A9H      ; AD_65
        DB    0AAH      ; AD_66
        DB    0AAH      ; AD_67
        DB    0AAH      ; AD_68
        DB    0ABH      ; AD_69
        DB    0ACH      ; AD_6A
        DB    0ACH      ; AD_6B
        DB    0ADH      ; AD_6C
        DB    0ADH      ; AD_6B
        DB    0ADH      ; AD_6E
        DB    0AEH      ; AD_6F

;AD 70h
        DB    0AEH      ; AD_70
        DB    0AEH      ; AD_71
        DB    0AFH      ; AD_72
        DB    0AFH      ; AD_73
        DB    0B0H      ; AD_74
        DB    0B1H      ; AD_75
        DB    0B1H      ; AD_76
        DB    0B2H      ; AD_77
        DB    0B2H      ; AD_78
        DB    0B2H      ; AD_79
        DB    0B3H      ; AD_7A
        DB    0B3H      ; AD_7B
        DB    0B3H      ; AD_7C
        DB    0B4H      ; AD_7B
        DB    0B4H      ; AD_7E
        DB    0B4H      ; AD_7F

;AD 80h
        DB    0B4H      ; AD_80
        DB    0B5H      ; AD_81
        DB    0B5H      ; AD_82
        DB    0B5H      ; AD_83
        DB    0B6H      ; AD_84
        DB    0B6H      ; AD_85
        DB    0B6H      ; AD_86
        DB    0B6H      ; AD_87
        DB    0B6H      ; AD_88
        DB    0B7H      ; AD_89
        DB    0B7H      ; AD_8A
        DB    0B7H      ; AD_8B
        DB    0B7H      ; AD_8C
        DB    0B7H      ; AD_8B
        DB    0B7H      ; AD_8E
        DB    0B8H      ; AD_8F
```

```
;AD 90h
        DB    0B8H      ; AD_90
        DB    0B8H      ; AD_91
        DB    0B8H      ; AD_92
        DB    0B8H      ; AD_93
        DB    0B8H      ; AD_94
        DB    0B9H      ; AD_95
        DB    0B9H      ; AD_96
        DB    0B9H      ; AD_97
        DB    0BAH      ; AD_98
        DB    0BAH      ; AD_99
        DB    0BAH      ; AD_9A
        DB    0BAH      ; AD_9B
        DB    0BAH      ; AD_9C
        DB    0BBH      ; AD_9B
        DB    0BBH      ; AD_9E
        DB    0BBH      ; AD_9F

;AD A0h
        DB    0BBH      ; AD_A0
        DB    0BBH      ; AD_A1
        DB    0BBH      ; AD_A2
        DB    0BCH      ; AD_A3
        DB    0BCH      ; AD_A5
        DB    0BCH      ; AD_A6
        DB    0BCH      ; AD_A7
        DB    0BCH      ; AD_A8
        DB    0BCH      ; AD_A9
        DB    0BDH      ; AD_AA
        DB    0BDH      ; AD_AB
        DB    0BDH      ; AD_AC
        DB    0BDH      ; AD_AB
        DB    0BDH      ; AD_AE
        DB    0BDH      ; AD_AF


;AD B0h
        DB    0BDH      ; AD_B0
        DB    0BEH      ; AD_B1
        DB    0BEH      ; AD_B2
        DB    0BEH      ; AD_B3
        DB    0BEH      ; AD_B4
        DB    0BFH      ; AD_B5
        DB    0BFH      ; AD_B6
        DB    0BFH      ; AD_B7
        DB    0C0H      ; AD_B8
        DB    0C0H      ; AD_B9
        DB    0C0H      ; AD_BA
        DB    0C0H      ; AD_BB
        DB    0C0H      ; AD_BC
        DB    0C0H      ; AD_BB
        DB    0C0H      ; AD_BE
        DB    0C0H      ; AD_BF

;AD C0h
        DB    0C0H      ; AD_C0
        DB    0C0H      ; AD_C1
        DB    0C0H      ; AD_C2
```

```
        DB    0C0H      ; AD_C3
        DB    0C0H      ; AD_C4
        DB    0C0H      ; AD_C5
        DB    0C0H      ; AD_C6
        DB    0C0H      ; AD_C7
        DB    0C2H      ; AD_C8
        DB    0C2H      ; AD_C9
        DB    0C4H      ; AD_CA
        DB    0C6H      ; AD_CB
        DB    0C8H      ; AD_CC
        DB    0CAH      ; AD_CB
        DB    0CBH      ; AD_CE
        DB    0D0H      ; AD_CF

;AD D0h
        DB    0D0H      ; AD_D0
        DB    0D0H      ; AD_D1
        DB    0D0H      ; AD_D2
        DB    0D0H      ; AD_D3
        DB    0D0H      ; AD_D4
        DB    0D0H      ; AD_D5
        DB    0D0H      ; AD_D6
        DB    0D0H      ; AD_D7
        DB    0D0H      ; AD_D8
        DB    0D0H      ; AD_D9
        DB    0D0H      ; AD_DA
        DB    0D0H      ; AD_DB
        DB    0D0H      ; AD_DC
        DB    0D0H      ; AD_DB
        DB    0D0H      ; AD_DE
        DB    0D0H      ; AD_DF

;AD E0h
        DB    0D0H      ; AD_E0
        DB    0D0H      ; AD_E1
        DB    0D0H      ; AD_E2
        DB    0D0H      ; AD_E3
        DB    0D0H      ; AD_E4
        DB    0D0H      ; AD_E5
        DB    0D0H      ; AD_E6
        DB    0D0H      ; AD_E7
        DB    0D0H      ; AD_E8
        DB    0D0H      ; AD_E9
        DB    0D0H      ; AD_EA
        DB    0D0H      ; AD_EB
        DB    0D0H      ; AD_EC
        DB    0D0H      ; AD_EB
        DB    0D0H      ; AD_EE
        DB    0D0H      ; AD_EF

;AD F0h
        DB    0D0H      ; AD_F0
        DB    0D0H      ; AD_F1
        DB    0D0H      ; AD_F2
        DB    0D0H      ; AD_F3
        DB    0D0H      ; AD_F4
        DB    0D0H      ; AD_F5
        DB    0D0H      ; AD_F6
```

```
DB   0D0H      ; AD_F7
DB   0D0H      ; AD_F8
DB   0D0H      ; AD_F9
DB   0D0H      ; AD_FA
DB   0D0H      ; AD_FB
DB   0D0H      ; AD_FC
DB   0D0H      ; AD_FB
DB   0D0H      ; AD_FE
DB   0D0H      ; AD_FF

end
```

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