Compressor Induction Motor Stall and Rotation Detection using Microcontrollers

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1 Introduction

Domestic refrigeration appliances commonly use single-phase induction motors to drive a compressor pump. The compressor is used to provide and maintain the required refrigerant pressure to allow the fridge compartment to function within the desired pre-selected temperature range. This application note provides a method of detecting a motor stall condition and a means for monitoring rotation during normal run conditions. Motor stall/rotation detection is based on a phase difference measurement between the run and start windings of the motor. This is achieved very conveniently using the timer input capture features available on the Freescale HC908KX8 low cost high performance ‘flash’ Microcontroller.

There is a necessity to provide some form of protection from conditions that may cause the motor windings to sustain thermal damage during start-up. This can be caused by a motor stall condition. If the motor is stalled, overheating will occur fairly rapidly and may cause permanent damage to the Motor windings. For example, mechanical failure of the compressor pump may impair the rotation of the motor and result in a stall condition.
Compressor motors in today’s refrigeration appliances are thermally protected by a bi-metallic contact that is embedded in the motor windings. This contact is in series with the AC line supply to the motor and will open and remove power to the motor when overheating occurs, for example, due to a motor stall condition. This method is suitable only for providing thermal protection of the motor windings. From power-on this can be achieved more efficiently and economically using a Freescale Microcontroller Embedded Solution. The Microcontroller solution has the additional advantage of providing a method of stall detection by detecting the rotation of the motor at start-up and monitoring rotation during normal run conditions.

2 AC Line Zero Cross Detection Hardware

Implementing an efficient motor start procedure can be achieved using a Triac and relay control technique. This involves firstly applying power to the run winding of the motor using the Relay. The Triac is connected in series with the start winding and is fired close to the zero crossing points of the line voltage for a specific period of time to start the motor. After this period the Triac is turned off and the motor continues to run. The start winding provides the initial starting torque and, after the motor has started, it has no further duty until the motor is powered down and re-started. A schematic diagram of the hardware required follows.
2.1 Detection Schematic

When running, the continuous rotational motion of the motor and magnetic field induces a voltage in the now redundant start winding. During normal running conditions there is a measurable phase difference between the start and run windings. This is illustrated in the following diagrams.
2.1.1 Run and Start Winding Before Rotation

In the above stalled condition the windings are in phase.

2.1.2 Phase Difference During Run Condition

Normal run conditions yields a phase difference between the run and start windings.
2.2 Phase Difference Measurement Process

The phase difference between the start and run windings is approximately 1mS. The presence of this difference is an indication of motor rotation. When the motor is not rotating, there is no difference in phase between the start and run windings. This change in behavior provides the measurement source for the Microcontroller. The following diagram illustrates the measurement process.

The 'phase shift' is the actual phase difference between the run and start windings. 'phase min' and 'phase max' define the acceptable tolerance band for the detection of the start zero cross point from the run zero cross reference point.

2.3 AC Line Signal Conditioning

The zero cross detect circuit conditions the above waveforms into usable digital signals which result as a series of pulses switched between 0V and Vdd at half the period of the AC line frequency, in this case 10mS. The digital signals derived from the zero crossing points of the run and
start windings are input to the Microcontroller input capture pins. A sample of the digital waveforms applied to the input capture pins follows.

2.3.1 Input to Microcontroller Before Rotation

![Graph showing input waveforms before rotation]

2.3.2 Input to Microcontroller During Run Condition

![Graph showing input waveforms during run condition]

This is the digital representation of the phase difference between the run and start windings during normal running conditions.
2.4 Detection Algorithm

The algorithm will monitor the continuous presence of pulses on the input capture pins derived from the run and start windings. If the pulses are not detected in the appropriate sequence and time frame, the motor can be considered as being in a stalled condition and appropriate action can be taken, for example, by removing power from the motor and raising an audible alarm. Alternatively, one input capture pin can be used to monitor the run winding and the start winding can be monitored using an input port. This would require additional code to poll the port pin in a timely sense. The method described here takes advantage of both input captures.

2.5 Consecutive Detection

The detection operation is as follows. Every time a zero crossing point is detected on the run winding, it is expected that a zero cross point should be detected on the start winding approximately 1mS later. The timing between the run and start zero cross points is measured with an appropriate tolerance band included in the measurement.

The algorithm is arranged to use the run zero cross points as a time reference. Each time a ‘run’ zero cross point is detected, the ‘run’ interrupt service routine is entered and the time of this event is latched. Approximately 1mS later the start winding zero cross point will be detected and the ‘start’ interrupt service routine will be entered. The time of this event will be latched also.

It is reasonable to expect that noise can influence the quality of the detected signal from either the start or run winding, and to compensate for this possibility, the algorithm will expect that zero cross detections should be consecutive. If for example a ‘run’ winding zero cross point is detected and the corresponding ‘start’ zero cross point is not detected within the expected time, this event will be identified as an error. A predefined number of non-consecutive zero cross errors will be tolerated before power-down and alarm action is invoked.
3 Flowcharts

The following flowcharts demonstrate an algorithm which implements stall/rotation detection of an induction motor refrigeration compressor. The algorithm is implemented from a main routine that controls the detection through two interrupt service routines, and also controls the power to the motor. It includes the facility to raise an audible alarm when the motor rotation is not in the expected state.
Stall Detect
Main Routine

```
main

Initialise device & application parameters

motor power 'on'

stall detect requested

Yes
stall detect enable

No
stall detect disable

motor stalled

Yes

No

motor power 'off'

alarm 'on'
```
Motor ‘On’ Routine

call from main

power-up motor

motor status ‘on’

return
Enable Stall Detect Routine

```
call from main

enable stall detect input capture

return
```

Disable Stall Detect Routine

```
call from main

disable stall detect input capture

return
```
Motor 'Off' Routine

1. call from main
2. power-down motor
3. motor status 'off'
4. return

Alarm 'On' Routine

1. call from main
2. alarm on
3. return
AC Line Zero
Cross Detect Input
Capture Interrupt
Routine

icap interrupt

start phase

time = 40mS

start phase expired

Yes

No

fire triac

increment 'start phase' count

read zero
cross detect
time

disable zero
cross detect

reset start
phase

reset input
capture flag

return
Start Winding Zero Cross Detect Interrupt Routine

1. motor stall detect interrupt
2. read start zero cross time from timer
3. increment start zero cross count
4. calculate phase shift
5. if phase shift valid
   1. yes
      1. reset consecutive error count
      2. increment consecutive error count
      3. return
   2. no
      1. reset phase shift valid count
5. if phase shift valid count equals start zero cross count
6. reset consecutive error count
7. increment consecutive error count
8. are consecutive phase shift errors equal to 10
9. if yes
   1. set 'motor stalled' flag
   2. clear 'motor stalled' flag
   3. reset input capture flag
   4. return
10. no
    1. increment consecutive error count
    2. return
4 Summary

There are many situations where it is convenient and sometimes necessary to have confirmation that the motor is in fact rotating when power is applied to the compressor. In the conventional arrangement the motor was protected from thermal damage by a bi-metallic contact. The Microcontroller can now manage this situation, decisions can be taken in the software based on the zero cross detection events of the run and start windings. In this way the motor can be protected from taking excessive power when in a stalled condition, therefore excessive winding temperature situations can be prevented from power-on. Additional thermal protection can also be included by connecting a sensor to the analogue to digital converter to continuously monitor motor temperature.

In applications that demand increased operational safety, knowing that the motor is rotating can be used as a comparative reference parameter for closed loop system integrity, safety measurements, or logic state confirmation checks. For example, in a pressurised system, if motor rotation is confirmed it can be expected that some time later the system should have achieved a specific pressure value. This can be measured using a pressure sensor and one of the analogue to digital converter inputs of the Microcontroller. Flow measurement can be achieved using a simple in-line switch connected to the device input/output ports. In these situations the Microcontroller can confirm motor rotation and compare with the feedback parameters measured within the software control loop.

Single-phase induction motors are widely used in ratings of 1hp and less, rarely greater than 10 hp. This power range of motors can meet the low through higher starting torque demands which are required for many household and industrial appliances, such as fans, which have a low starting torque and the higher starting torque demands of pumps, air conditioning units, and refrigeration compressors. As well as being a cost-effective solution, the adaptability and programmability of the Microcontroller can make a significant impact in the control, safety and efficiency of these and appliances.
5 Code

During the initial start-up phase, the probability of a stall condition is higher. This typically can be caused by mechanical failure where the motor is unable to start due to an obstruction, or an electrical failure when the motor is unable to start due to internal winding damage or component failure. However, it may be convenient in some systems to extend this feature to monitor the rotation of the motor at any time during the normal operational cycle of the application. The following code has been structured such that functions can be included in the application and called at any time from power-on in a convenient way. A main routine is used to demonstrate the implementation of the code as described in the preceding flowcharts.
#include "hc08kx8.h" /* generic hc08kx8 header file*/
#include "stall.h" /* application header file */

5.1 Main Routine

/**************************************************************************
Copyright (c)
Function Name : main()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Main routine applies power to the motor, enables or disables stall detection and powers the motor down based on the condition of a flag which is controlled in the stall detect ISR.
**************************************************************************/

void main(void)
{
    init();
    motor_on();
    while(1)
    {
        if(STALL_DETECT_SELECT == ENABLED) /* port pin high */
        {
            stall_detect_enable(); /* enable stall detect input capture */
            if(motor_stalled) /* after start phase expired */
            {
                motor_off(); /* remove power from motor */
                alarm_on(); /* audible alarm */
            }
        }
        else
        {
            stall_detect_disable();
        }
    }
}
5.2 Initialisation Routine

/******************************************************************************
Copyright (c)
Function Name : init()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Function configures oscillator, device modules and initialises application parameters
******************************************************************************/

void init(void)
{
    config(); /* sets configuration register */
    init_osc(); /* sets oscillator frequency */
    init_ports(); /* configure input/output ports */
    init_timer(); /* initialise timer */
    init_icap(); /* configure input capture pin */
    init_application(); /* initialises application parameters */
}

5.3 Configuration Routine

/******************************************************************************
Copyright (c)
Function Name : config()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Function configures device configuration register
******************************************************************************/

void config()
{
    CONFIG1= 0x31; /* disables lvi and cop */
}

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Go to: www.freescale.com
5.4 Oscillator Initialisation Routine

/******************************************************************************
Copyright (c)
Function Name : init_osc()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Function sets oscillator frequency
******************************************************************************/

void init_osc(void)
{
    ICGMR_N0 = SET; /* set oscillator frequency */
    ICGMR_N1 = RESET; /* multiplier set for 29x307.2khz = 8.9Mhz */
    ICGMR_N2 = SET; /* = 2.27Mhz bus freq */
    ICGMR_N3 = SET;
    ICGMR_N4 = SET;
    ICGMR_N5 = RESET;
    ICGMR_N6 = RESET;
}

5.5 Initialise Input Output Ports Routine

/************************************************************
Function Name : init_ports()
Engineer : William Mackay
Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Configures input output ports
**************************************************************************/

void init_ports(void)
{
   DDRA_BIT0 = OUTPUT; /* relay */
   DDRA_BIT1 = OUTPUT; /* buzzer */
   DDRA_BIT4 = INPUT; /* door */
   PTAPUE_BIT4 = SET; /* enable pull-up */

   DDRB_BIT0 = INPUT; /* UPDATE check adc init air temp adc */
   DDRB_BIT1 = INPUT; /* evaporator temp adc */
   DDRB_BIT2 = INPUT; /* temp select */
   DDRB_BIT3 = OUTPUT; /* yellow motor 'on' led */
   DDRB_BIT6 = OUTPUT; /* triac drive */
   DDRB_BIT5 = OUTPUT; /* power 'on' red led */
   DDRB_BIT4 = OUTPUT; /* alarm on-green led */
}
5.6 Timer Initialisation Routine

/**************************************************************************
Copyright (c)
Function Name : init_timer()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Function used to configure timer interface module.
Sets internal bus clock pre-scalar for timer counter
**************************************************************************/

void init_timer(void)
{
    TSC = RESET; /* internal bus clock divide by 1 */
}
5.7 Input Capture Initialisation Routine

/***************************************************************************/
Copyright (c)

Function Name : init_icap()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : This function configures timer channel zero and Channel 1 as input capture for rising and falling edge detection

***************************************************************************/

void init_icap(void)
{
    TSC_TSTOP = RESET; /* start timer */
    TSC0_MS0A = RESET; /* mode select = input capture */
    TSC0_MS0B = RESET;
    TSC0_ELS0A = SET; /* capture on rising or falling edge */
    TSC0_ELS0B = SET;
    TSC0_CH0IE = RESET; /* enable interrupts */
    TSC1_MS1A = RESET; /* mode select = input capture */
    TSC1_ELS1A = SET; /* capture on rising or falling edge */
    TSC1_ELS1B = SET;
    TSC1_CH1F = RESET; /* clear flag*/
    TSC1_CH1IE = SET; /* enable interrupts */
}
5.8 Initialise Application Routine

/***************************************************************************/
Copyright (c)
Function Name : init_application()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Function initialises application parameters
***************************************************************************/

void init_application()
{
  POWER_STATUS = ON; /* red led */
  MOTOR_POWER = DISABLED; /* motor relay de-energised */
  MOTOR_STATUS = OFF; /* green led */
  TRIAC_DRIVE = DISABLED; /* triac off */
  BUZZER = OFF;
  ALARM_STATUS = OFF; /* yellow led */
  ZERO_CROSS_DETECT = ENABLED; /* start motor at next zero cross */
  stall_detect_disable(); /* enable stall detect input capture */
  ENABLE_INTERRUPTS; /* enable interrupts */
}

5.9 Motor ‘on’ Routine

/***************************************************************************/
Copyright (c)
Function Name : motor_on()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Function powers-on motor
***************************************************************************/

void motor_on(void)
{
  MOTOR_POWER = ENABLED; /* motor relay energised */
  MOTOR_STATUS = ON;
}
5.10 Stall Detect Enable Routine

/*******************************************************************************
Copyright (c)
Function Name : stall_detect_enable()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Enables stall detection
*******************************************************************************/
void stall_detect_enable()
{
   if(start_phase == RESET /* initial motor start phase complete */
   {
      MOTOR_STALL_DETECT = ENABLED;
   }
}

5.11 Motor ‘off’ Routine

/*******************************************************************************
Copyright (c)
Function Name : motor_off()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Function powers-down motor
*******************************************************************************/
void motor_off(void)
{
   MOTOR_POWER = DISABLED; /* motor relay de-energised */
   ZERO_CROSS_DETECT = DISABLED; /* disable icap interrupt */
   MOTOR_STATUS = OFF; /* motor led */
}
5.12 Alarm ‘on’ Routine

/*******************************************************************************
Copyright (c)
Function Name : alarm_on()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Function invokes alarm status and audible alarm
*******************************************************************************/

void alarm_on(void)
{
    ALARM_STATUS = ON;
    BUZZER = ON;
}

5.13 Stall Detect Disable Routine

/*******************************************************************************
Copyright (c)
Function Name : stall_detect_disable()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : Disables stall detection
*******************************************************************************/

void stall_detect_disable()
{
    if(start_phase == RESET) /* initial motor start phase complete */
    {
        MOTORSTALL_DETECT = DISABLED;
    }
}
5.14 Delay Routine

/***************************************************************************/
Copyright (c)

Function Name : delay()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0

Note : This delay for triac pulse period
/***************************************************************************/

void delay(void)
{
    unsigned char i, j;
    for (i = 0; i < 2; i++)
    {
        for (j = 0; j < 1; j++);
    }
}
5.15 Input Capture Routine

/***************************************************************************
Copyright (c)

Function Name : input_capture()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0

This ISR pulses the triac when line voltage zero-cross is detected, for a pre-defined motor start period
***************************************************************************/

#pragma TRAP_PROC SAVE_REGS
void Input_Capture(void)
{
    if(start_phase != START_TIME /* start phase valid */
    {
        TRIAC_DRIVE = OFF; /* apply pulse to triac */
        delay();
        TRIAC_DRIVE = ON;
        ++start_phase; /* start phase is a count of the */
        /* line voltage zero cross points */
    }
    else
    {
        timer_ch0.count.timer_high = TIMER_CH0_HIGH; /* read high byte of counter */
        timer_ch0.count.timer_low = TIMER_CH0_LOW; /* read low byte of counter */
        ZERO_CROSS_DETECT = DISABLED; /* disable timer ch 0 icap interrupt */
        MOTOR_STALL_DETECT = ENABLED; /* enable timer ch1 icap interrupt */
        start_phase = RESET; /* reset start phase */
    }
    read_register = TSC0; /* reads TIM status and control regr */
    ICAP0_FLAG = RESET; /* resets CHOF flag */
}
5.16 Stall Detection Routine

/***************************************************************************
Copyright (c)
Function Name : stall_detect()
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Note : This ISR detects the induced voltage in the motor start winding after the initial start phase has expired.
***************************************************************************/

#pragma TRAP_PROC SAVE_REGS
void Stall_Detect(void)
{
    timer_ch1.count.timer_high = TIMER_CH1_HIGH; /* read high byte of counter */
    timer_ch1.count.timer_low = TIMER_CH1_LOW; /* read low byte of counter */
    ++start_zero_cross; /* cumulative count of start zero cross points */
    if(timer_ch1.timer_count > timer_ch0.timer_count)
    {
        phase_shift = (timer_ch1.timer_count - timer_ch0.timer_count);
    }
    else
    {
        phase_shift = (TIMER_COUNT_MAX - timer_ch0.timer_count + timer_ch1.timer_count);
        /*accomodates counter rollover */
    }
    if((timer_ch1.timer_count >= (timer_ch0.timer_count + phase_shift - PHASE_MIN))&&
    (timer_ch1.timer_count <= (timer_ch0.timer_count + phase_shift + PHASE_MAX)))
    {
        ++phase_shift_valid; /* cumulative count of valid phase shifts */
    }
    else
    {
        phase_shift_valid = RESET;
    }
    if(phase_shift_valid != start_zero_cross) /* both counts are not the same */
    {
        ++consecutive_error; /* cumulative count of phase shift errors */
    }
    else
    {
        consecutive_error = RESET;
    }
    if(consecutive_error >= PHASE_ERROR_COUNT_MAX)
    {
        motor_stalled = SET; /* indicates motor has stalled */
    }
    else
    {
        motor_stalled = RESET; /* motor is rotating */
    }
    read_register = TSC1; /* reads TIM status and control regr */
    ICAP1_FLAG = RESET; /* resets CH1F flag */
}
5.17 HC08KX8 Generic Header File

****************************************************************************
Copyright (c)
File Name : HC08KX8.h
Org Author : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : December 1999
Current Revision : 0.0
Notes : This file maps the 68HC908KX8 register set as defined in the General Release Specification.
*****************************************************************************

#ifndef _HC08KX8_H
#define _HC08KX8_H

/****************************************************************************/
/* Register Mapping Structures and Macros */
/****************************************************************************/
#define REGISTER(a) (*((volatile unsigned char *)(a)))
#define BIT(a,b) (((vbitfield *)(a))->bit##b)
/* assumes right to left bit order */
typedef volatile struct{
 volatile unsigned int bit0 : 1;
 volatile unsigned int bit1 : 1;
 volatile unsigned int bit2 : 1;
 volatile unsigned int bit3 : 1;
 volatile unsigned int bit4 : 1;
 volatile unsigned int bit5 : 1;
 volatile unsigned int bit6 : 1;
 volatile unsigned int bit7 : 1;
} vbitfield;
typedef union
{
 struct{
 unsigned char timer_high;
 unsigned char timer_low;
 } count;
 unsigned short timer_count;
} TIMER;

TIMER timer_ch0;
TIMER timer_ch1;
/****************************************************************************/
/* Input Output Ports */
/******************************************************************************/

/* Port A Data register */
#define PTA REGISTER(0x00)
#define PTA_BIT0 BIT(0x00,0)
#define PTA_BIT1 BIT(0x00,1)
#define PTA_BIT2 BIT(0x00,2)
#define PTA_BIT3 BIT(0x00,3)
#define PTA_BIT4 BIT(0x00,4)

/* Port B Data register */
#define PTB REGISTER(0x01)
#define PTB_BIT0 BIT(0x01,0)
#define PTB_BIT1 BIT(0x01,1)
#define PTB_BIT2 BIT(0x01,2)
#define PTB_BIT3 BIT(0x01,3)
#define PTB_BIT4 BIT(0x01,4)
#define PTB_BIT5 BIT(0x01,5)
#define PTB_BIT6 BIT(0x01,6)
#define PTB_BIT7 BIT(0x01,7)

/* Port A Data Direction Register */
#define DDRA REGISTER(0x04)
#define DDRA_BIT0 BIT(0x04,0)
#define DDRA_BIT1 BIT(0x04,1)
#define DDRA_BIT2 BIT(0x04,2)
#define DDRA_BIT3 BIT(0x04,3)
#define DDRA_BIT4 BIT(0x04,4)

/* Port A Input Pull Up Enable Register */
#define PTAPUE REGISTER(0x0D)
#define PTAPUE_BIT0 BIT(0x0D,0)
#define PTAPUE_BIT1 BIT(0x0D,1)
#define PTAPUE_BIT2 BIT(0x0D,2)
#define PTAPUE_BIT3 BIT(0x0D,3)
#define PTAPUE_BIT4 BIT(0x0D,4)

/* Port B Data Direction Register */
#define DDRB REGISTER(0x05)
#define DDRB_BIT0 BIT(0x05,0)
#define DDRB_BIT1 BIT(0x05,1)
#define DDRB_BIT2 BIT(0x05,2)
#define DDRB_BIT3 BIT(0x05,3)
#define DDRB_BIT4 BIT(0x05,4)
#define DDRB_BIT5 BIT(0x05,5)
#define DDRB_BIT6 BIT(0x05,6)
#define DDRB_BIT7 BIT(0x05,7)
# Application Note

## HC08KX8 Generic Header File

**AN2149**

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### Time Base Register

```c
#define TBCR REGISTER(0x1C)
#define TBCR_TBON BIT(0x1C,1)
#define TBCR_TBIE BIT(0x1C,2)
#define TBCR_TACK BIT(0x1C,3)
#define TBCR_TBR0 BIT(0x1C,4)
#define TBCR_TBR1 BIT(0x1C,5)
#define TBCR_TBR2 BIT(0x1C,6)
#define TBCR_TBIF BIT(0x1C,7)
```

### Configuration Write-Once Registers

```c
#define CONFIG2 REGISTER(0x1e)
#define CONFIG1 REGISTER(0x1F)
```

### Timer Registers

#### Timer Status and Control Register

```c
#define TSC REGISTER(0x20)
#define TSC_PS0 BIT(0x20,0)
#define TSC_PS1 BIT(0x20,1)
#define TSC_PS2 BIT(0x20,2)
#define TSC_TRST BIT(0x20,4)
#define TSC_TSTOP BIT(0x20,5)
#define TSC_TOIE BIT(0x20,6)
#define TSC_TOF BIT(0x20,7)
```

#### Timer Counter Register

```c
#define TCNTH REGISTER(0x21)
#define TCNTL REGISTER(0x22)
```

#### Timer Modulo Register

```c
#define TMODH REGISTER(0x23)
#define TMODL REGISTER(0x24)
```

#### Timer Status and Control Register Channel 0

```c
#define TSC0 REGISTER(0x25)
#define TSC0_CH0MAX BIT(0x25,0)
#define TSC0_TOV0 BIT(0x25,1)
#define TSC0_ELS0A BIT(0x25,2)
#define TSC0_ELS0B BIT(0x25,3)
#define TSC0_MS0A BIT(0x25,4)
#define TSC0_MS0B BIT(0x25,5)
#define TSC0_CH0IE BIT(0x25,6)
#define TSC0_CH0F BIT(0x25,7)
```
/* Timer Channel 0 Register */
#define  TCH0H  REGISTER(0x26)
#define  TCH0L  REGISTER(0x27)

/* Timer Status and Control Register Channel 1 */
#define  TSC1  REGISTER(0x28)
#define  TSC1_CH1MAX  BIT(0x28,0)
#define  TSC1_TOV1  BIT(0x28,1)
#define  TSC1_ELS1A  BIT(0x28,2)
#define  TSC1_ELS1B  BIT(0x28,3)
#define  TSC1_MS1A  BIT(0x28,4)
#define  TSC1_CH1IE  BIT(0x28,6)
#define  TSC1_CH1F  BIT(0x28,7)

/* Timer Channel 1 Register */
#define  TCH1H  REGISTER(0x29)
#define  TCH1L  REGISTER(0x2a)

/****************************************************************************/
/* ICG Registers */
/****************************************************************************/

/* ICG Control Register */
#define  ICGCR  REGISTER(0x36)
#define  ICGCR_ECGS  BIT(0x36,0)
#define  ICGCR_ECGON  BIT(0x36,1)
#define  ICGCR_ICGS  BIT(0x36,2)
#define  ICGCR_ICGON  BIT(0x36,3)
#define  ICGCR_CS  BIT(0x36,4)
#define  ICGCR_CMON  BIT(0x36,5)
#define  ICGCR_CMF  BIT(0x36,6)
#define  ICGCR_CMIE  BIT(0x36,7)

/* ICG Multiply Register */
#define  ICGMR  REGISTER(0x37)
#define  ICGMR_N0  BIT(0x37,0)
#define  ICGMR_N1  BIT(0x37,1)
#define  ICGMR_N2  BIT(0x37,2)
#define  ICGMR_N3  BIT(0x37,3)
#define  ICGMR_N4  BIT(0x37,4)
#define  ICGMR_N5  BIT(0x37,5)
#define  ICGMR_N6  BIT(0x37,6)

/* ICG Trim Register */
#define  ICGTR  REGISTER(0x38)
#define  ICGTR_TRIM0  BIT(0x38,0)
#define  ICGTR_TRIM1  BIT(0x38,1)
#define  ICGTR_TRIM2  BIT(0x38,2)
#define  ICGTR_TRIM3  BIT(0x38,3)
#define  ICGTR_TRIM4  BIT(0x38,4)
#define  ICGTR_TRIM5  BIT(0x38,5)
#define  ICGTR_TRIM6  BIT(0x38,6)
#define  ICGTR_TRIM7  BIT(0x38,7)

/****************************************************************************/
/* Analogue To Digital Converter Registers */
/****************************************************************************/

/* A/D Status and Control Register */
#define ADSCR REGISTER(0x3c)
#define ADSCR_ADCH0 BIT(0x3c,0)
#define ADSCR_ADCH1 BIT(0x3c,1)
#define ADSCR_ADCH2 BIT(0x3c,2)
#define ADSCR_ADCH3 BIT(0x3c,3)
#define ADSCR_ADCH4 BIT(0x3c,4)
#define ADSCR_ADCO BIT(0x3c,5)
#define ADSCR_AIEN BIT(0x3c,6)
#define ADSCR_COCO BIT(0x3c,7)

/ * A/D-Data Register */
#define ADR REGISTER(0x3d)

/ * A/D Input Clock Register */
#define ADCLK REGISTER(0x3e)
#define ADCLK_ADICLK BIT(0x3e,4)
#define ADCLK_ADIV0 BIT(0x3e,5)
#define ADCLK_ADIV1 BIT(0x3e,6)
#define ADCLK_ADIV2 BIT(0x3e,7)

/**************************************************************************/
/* Low Voltage Inhibit Register */
/**************************************************************************/

/ * LVI Status Register */
#define LVISR REGISTER(0xFE0C)
#define LVISR_LVIOUT BIT(0xFE0C,7)

#error
5.18 Application Header File

/****************************************************************************
Copyright (c)
File Name : StallDetect.h
Engineer : William Mackay
Location : Freescale Microcontroller Division, East Kilbride
Date Created : March 2000
Current Revision : 0.0
Notes : This file contains application definitions
****************************************************************************/

ifndef _STALL_H
#define _STALL_H

/**************************************************************************/
/* Constant Definitions */
/**************************************************************************/
#define ON 0
#define OFF 1
#define SET 1
#define RESET 0
#define ENABLED 1
#define DISABLED 0
#define RESET 0
#define OUTPUT 1
#define INPUT 0
#define START_TIME 0x28 /* motor start-up period (40mS) */
#define STALL_PERIOD 0xFF /* 255x10mS = 2.55Sec 0x07 motor stall time period (3 cycles) */
#define TIMER_COUNT_MAX 0xFFFF /* maximum value of timer counter */
#define PHASE_MIN 0x0D50 /* 3408 */
#define PHASE_MAX 0x0470 /* 1136 */
#define PHASE_ERROR_COUNT_MAX 0x06

/**************************************************************************/
/* Input/Output Port Application Definitions */
/**************************************************************************/
#define MOTOR_POWER PTA_BIT0
#define BUZZER PTA_BIT1
#define STALL_DETECT_SELECT PTA_BIT4
#define TRIAC_DRIVE PTB_BIT6
#define POWER_STATUS PTB_BIT5
#define MOTOR_STATUS PTB_BIT3
#define ALARM_STATUS PTB_BIT4

#endif

/#*************************************************************************/
/# /* Timer */
/#*************************************************************************/

#define ZERO_CROSS_DETECT TSC0_CH0IE
#define ICAP0_FLAG TSC0_CH0F
#define MOTORSTALL_DETECT TSC1_CH1IE
#define ICAP1_FLAG TSC1_CH1F
#define TIMERCH0_HIGH TCH0H
#define TIMERCH0_LOW TCH0L
#define TIMERCH1_HIGH TCH1H
#define TIMERCH1_LOW TCH1L

/#*************************************************************************/
/# /* Function Prototypes */
/#*************************************************************************/

void main(void);
void config(void);
void init(void);
void init_ports(void);
void init_osc(void);
void init_timer(void);
void init_icap(void);
void init_application(void);
void delay(void);
void stall_detect_enable(void);
void stall_detect_disable();
void motor_on(void);
void motor_off(void);
void power_down(void);
void alarm_on(void);
void Input_Capture(void);
void Stall_Detect(void);

/#*************************************************************************/
/# /* Global Variables */
/#*************************************************************************/

/#pragma DATA SEG _DATA_ZEROPAGE
unsigned char start_phase; /* indicates status of start time interval */
unsigned char motor_stalled; /* indicates motor start status */
unsigned char stall_time; /* count for permitted stall time */
unsigned char read_register; /* dummy read location for flag clearing */
unsigned char start_zero_cross; /* count */
unsigned int phase_shift; /* time storage */
unsigned char phase_shift_valid; /* count */
unsigned char consecutive_error; /* count */

/#*************************************************************************/
/# /* Interrupt Definitions */
/#*************************************************************************/

#define ENABLE_INTERRUPTS asm cli;
#define DISABLE_INTERRUPTS asm sei;

#endif

AN2149

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