Freescale Semiconductor
Application Note

AN2839
Rev. 0, 9/2004

Implementing a Lamp Dimmer with an HC908Q Family MCU

by: Jefferson Daniel de Barros Soldera
Andre Luis Vilas Boas
Alfredo Olmos
Marcus Espindola
Brazil Semiconductor Technology Center — BSTC/SPS

Introduction

Many homes have lamps that can be made brighter or dimmer by a control on the on/off switch. This application note describes how to implement a low-cost lamp brightness control or dimmer using a member of the M68HC08 MCU Family. The circuit controls the amount of energy that reaches the bulb during each half-cycle of the AC power line. Moreover, a microcontroller may grant extra automation features to the circuit, such as soft start and programmable timing. Additionally, an application in which a lamp is turned on for a specific amount of time is described. The dimmer circuit implementation requires few external components.

Dimmer Features

- 110 V or 220 V, 60 Hz or 50 Hz supply voltage
- Up to 100 W lamp dimming
- Full wave AC phase control
- No transformer for AC power isolation
- Up/down touch control option
- Customized programmable timer
- Low-cost 8-pin MCU implementation

Control Method

Many homes have lamps that can be made brighter or dimmer by rotating or sliding a control on the on/off switch. Years ago, this was done using a device called a rheostat which consists of a large variable resistor. To control the amount of energy going to the light, the rheostat had to dissipate the excess energy as heat. For example, at half brightness for a 100-watt bulb, approximately 20 W would be converted to heat in the rheostat.

Modern dimmers work in an entirely different way. They use transistor-like devices called triacs to switch on the current to a lamp part way into each half-cycle. Unlike the silicon-controlled rectifier (SCR), the triac can conduct current in both half-cycles when turned on. As soon as it is triggered, the triac will allow the current to flow through the bulb until that current gets to zero, which happens whenever the voltage crosses zero.

The amount of energy that reaches the bulb during each half-cycle depends on how long the control waits before triggering the triac. The longer it waits, the less energy reaches the bulb and it will glow.

Triacs

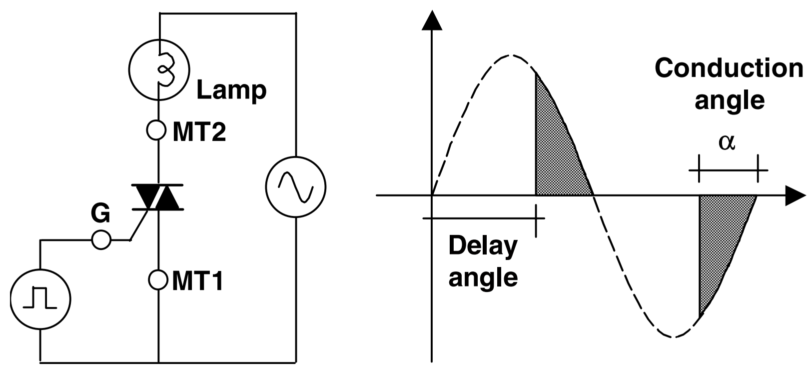
To successfully apply triacs for power control, an understanding of the triac's characteristics, ratings, and limitations is imperative.

Figure 1 shows the triac power control principle. Triacs are three-terminal AC semiconductor switches that are triggered into conduction when a low-energy signal is applied to their gate, allowing a full wave AC control. In Figure 1a, terminals MT1 and MT2 are the current-carrying terminals; G is the gate terminal used for triggering the device. To avoid confusion, it has become standard practice to specify all currents and voltages using MT1 as reference.

Triggering a triac requires meeting its gate energy specification. Therefore, the gate should be driven hard and fast to ensure complete gate turn-on, which helps to prevent false triggering. Usually that means a gate current of at least three times the gate turn-on current with a pulse train. It is also important to keep up the input trigger pulse synchronized with the AC power line in order to have a constant conduction angle.

The dashed region in Figure 1b corresponds to the voltage applied to the load. The *delay angle* is the angle, measured in electrical degrees, during which the device is blocking the line voltage. The period during which the device is on is called the *conduction angle* (α). Varying α will control the portion of the total AC sine wave applied to the load and, thereby, regulate the power flow to the load.

The main disadvantage of using phase control in triac applications is the generation of electro-magnetic interference (EMI). In incandescent lamps, phase control gives a continuous brightness and good performance.



a. Triac Symbol

b. Sine Wave Showing Phase Control Principles

Figure 1. Performing Power Control with Triac — Triggering the Device

HC908Q Family Features

High-performance 8-bit HC08 CPU:

- Object-code compatible with Freescale's 68HC05 architecture for easy migration
- Enables the higher performance required of many 8-bit applications while saving development time — as fast as 125 ns minimum instruction cycle time
- Designed to allow efficient, compact modular coding in assembly or C with full 16-bit stack pointer and stack relative addressing
- Efficient instruction set with multiply and divide that is easy to learn and use

Memory:

- In-application, in-circuit re-programmable FLASH memory (1.5K to 4K bytes)
- 128 bytes of random access memory (RAM)

Peripherals:

- Two-channel, 16-bit timer with selectable input capture, output compare, or PWM
- Trimmable 5% accuracy internal clock oscillator
- Four-channel, 8-bit analog-to-digital converter (ADC) (on the MC68HC908QT2/QT4/QY2/QY4) provides an easy interface to analog inputs such as sensors

- Flexible I/Os allow direct drive of LEDs and other circuits to eliminate external drivers and help reduce system cost
- System protection features, including watchdog timer and on-chip low-voltage detect/reset to help reduce cost and increase reliability
- Space-sensitive packages — 8 PDIP, 8 SOIC, 16 PDIP, 16 SOIC, and 16 TSSOP — with more to come as the Family develops

Application Description

The HC908Q Family allows the user to choose the MCU clock source. The microcontroller has three clock source options available. Because this application aims to be low cost, the clock frequency is internally generated. The internal oscillator circuit is designed to provide a clock source with tolerance less than ±25% untrimmed without external components. An 8-bit trimming register allows adjustment to a tolerance of less than ±5%.

Other possible choices, although more expensive and definitely not necessary for this sort of application, would be a built-in RC oscillator module that requires an external resistor connected to the chip. There is also a built-in XTAL oscillator module designed to operate with an external crystal or ceramic resonator to provide an accurate clock source.

The software accomplishes the brightness control by adjusting the conduction angle. The circuit does not require a transformer to supply DC voltage to the MCU. For this reason, the user must use caution during circuit assembly.

Figure 2 illustrates the complete schematic diagram of the dimmer. The supply voltage is connected to the AC line through the capacitor C1 that provides circuit isolation. C1 must be a 1 μF/ 600 V non-polarized polyester capacitor. The diodes D1 and D2 enforce the half-wave rectification and the capacitor C2 implements the ripple filtering. C3 is a ceramic bypass capacitor located as near as possible to the MCU power pins in order to suppress high-frequency noise. The zener diode helps provide a reasonable regulated voltage, which reduces the rectifier voltage to the desired supply voltage.

R1 and R2 provide the zero-crossing detection to the MCU to synchronize the triac trigger pulses with the AC power line, achieving an accurate control. All four diodes are 1n4007, which allows the circuit to be supplied by 115 V or 240 V AC.

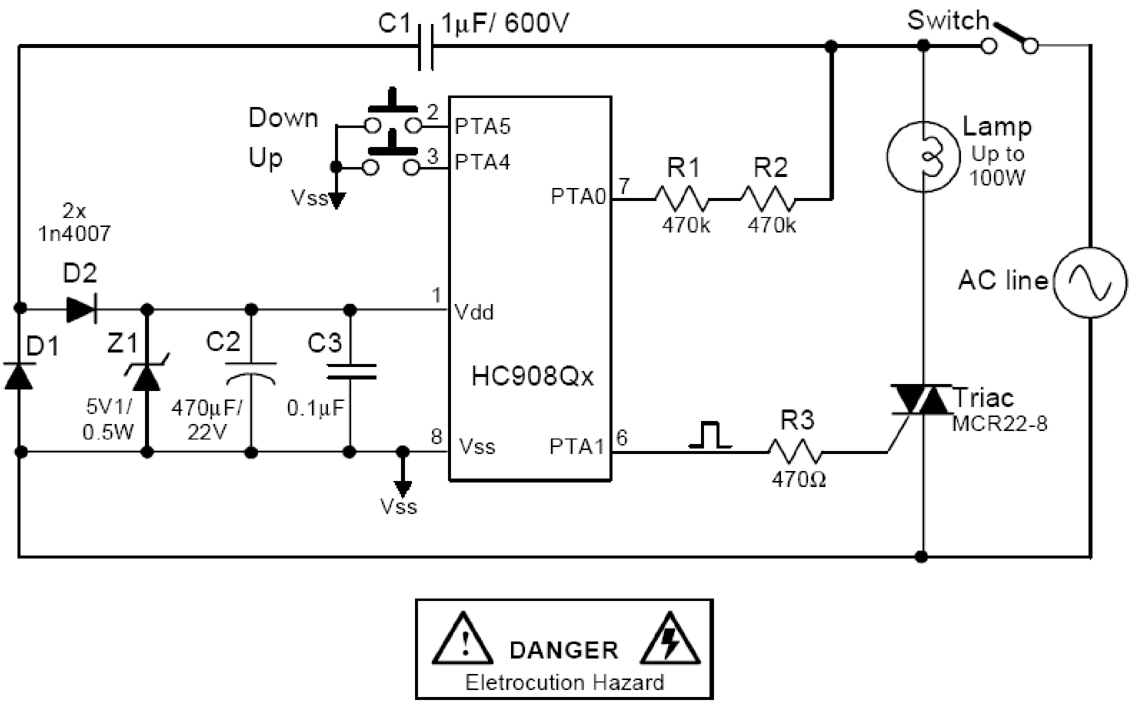


Figure 2. Dimmer with the HC908Q Family

The triac must be chosen according to the required load current. For a 100-W lamp, the load current at 115 V is 0.87 A and at 240 V, it is 0.42 A. Therefore, for the triac MCR22-8, 600 V isolation is a reasonable choice and can be used for both 115 V and 240 V AC. The resistor R3 limits the triac gate current.

All discrete devices in the circuit are not critical and similar devices can be substituted. The user must be careful about reverse voltage and direct current on diodes and zener, isolation voltage of capacitors, and maximum current in the triac.

Two push buttons and a switch are used to set the lamp brightness and turn the circuit on/off. When the up/down control is pressed, the MCU receives a low level and varies the conduction angle by shifting the short pulses that trigger the triac. The down button allows the MCU to apply pulses reducing α and the lamp brightness is reduced continuously. Conversely, the up button is used to increase α, which increases lamp brightness.

Because there is no transformer for power-line isolation, the user must be very careful during assembly and testing to provide the appropriate isolation from the AC power line.

Figure 3, Figure 4, and Figure 5 show the power line signal (a), zero-crossing reference signal (b), MCU short pulses triggering the triac (c), and the waveform of the voltage applied to the load at different average powers (d). Notice that only a portion of the sine wave is applied to the load. The average power is proportional to absolute average voltage.

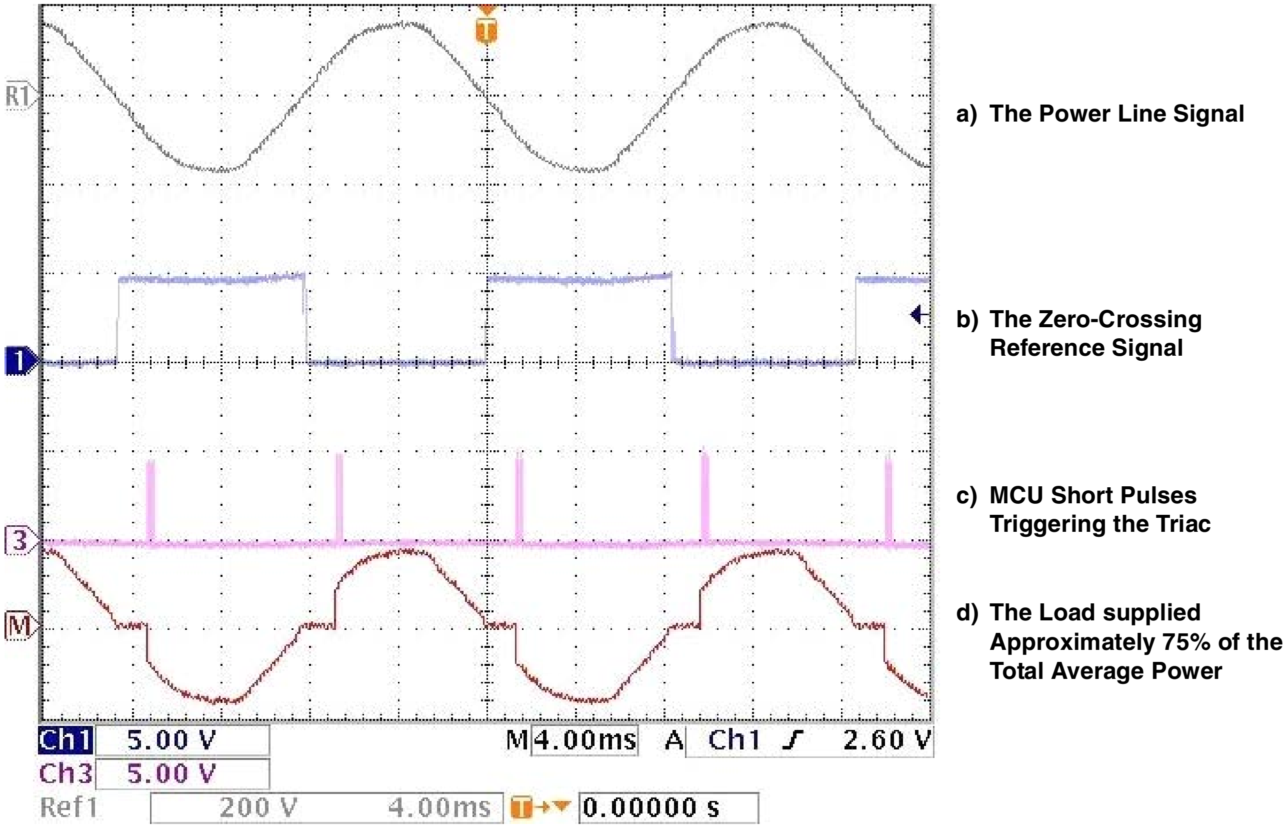


Figure 3. Triac Control with the HC908Q Family

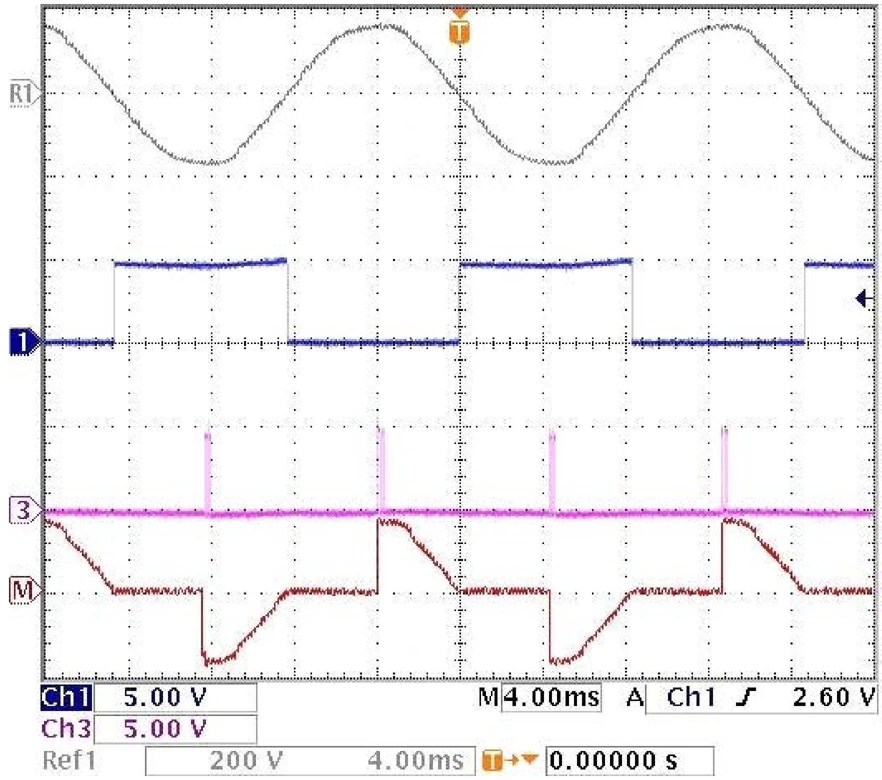


Figure 4. The Load Supplied at 50% of the Total Average Power

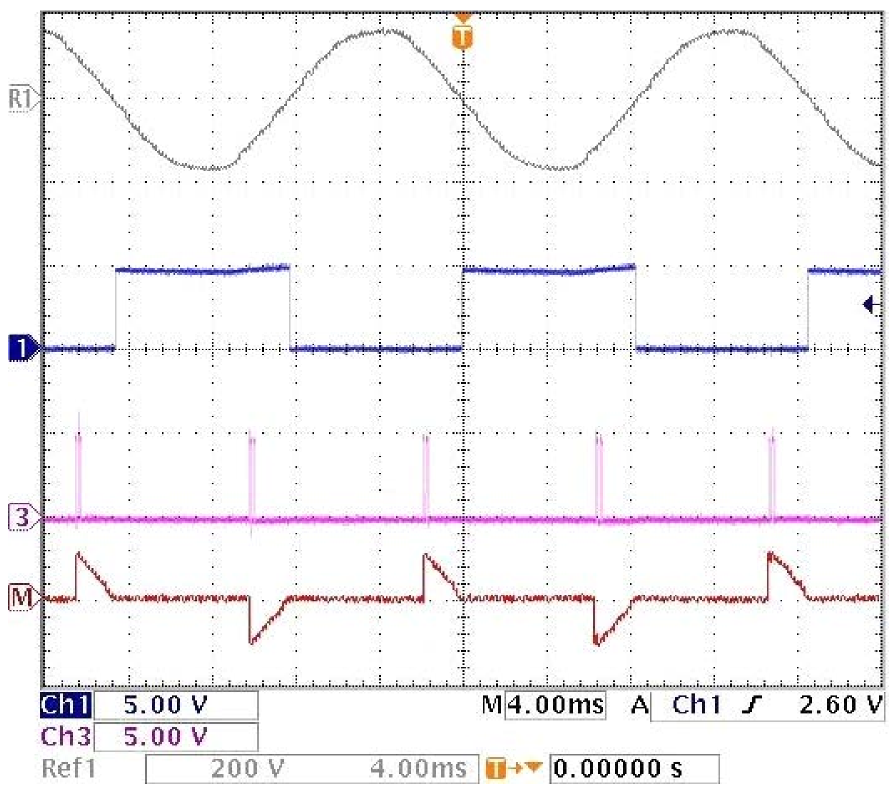


Figure 5. The Load Supplied Approximately 25% of the Total Average Power

Design Customization

This design works for many applications without modification. However, some customers may want to customize its functionality. A few variations for this circuit include:

- Modifying the circuit to use a single button. For this modification, pressing the button would turn the lamp on and off and if held would gradually brighten the lamp to full bright, then gradually dim to full dim. The brightness would stay at whatever level it was at when the button was released.
- Enhance the timer feature to allow the user to choose the period (“on” time).
- Add a sensor to automatically switch the lamp on and off based on the room occupancy.
- Use the two available pins to add a serial bus for control from a remote computer.
- Add a photo sensor to adjust a given brightness level in a room according to the ambient light.
- Isolate the load by an opto-isolator IC. This provides isolation between the load and the control circuit, especially when high isolation voltage is required. Applications involving industrial controls, vending machines, or motor controls would benefit from this technology. Figure 6 illustrates how to implement this type of modification. T1 must have a secondary of 9 V or 12 V so that the zener operates adequately.
- Another practical application is to keep the load turned on for a certain amount of time. In this case, the load is supplied at full power and the triac is triggered at a desired time. Refer to Figure 7 for a schematic diagram of the timer.

  When the start button is pressed, the MCU is reset and enters into run mode. The software counts the desired time (set previously) and enters into stop mode, which turns off the lamp. When the MCU is in stop mode, all internal modules are disabled and the power consumption is negligible. The circuit is kept in this state until the start button is pressed again.

  The software was set to a one minute delay time. This is the value used in most applications where it is required that a lamp must be turned on for a short time. However, the software can be easily be changed to set the desired delay time and lamp brightness.

  For higher loads (greater than 100 watts), the triac must be changed to accommodate the maximum current and a heat sink might be required. A high-current triac requires a non-negligible gate current and it might not be possible to drive the triac gate directly from an MCU port. In this case, a driver is needed.

NOTE

The circuits above control resistive loads only. For inductive loads, it is recommended that the MCU be isolated from the load with opto couplers and that a triac snubber network be adopted as shown in Figure 8.

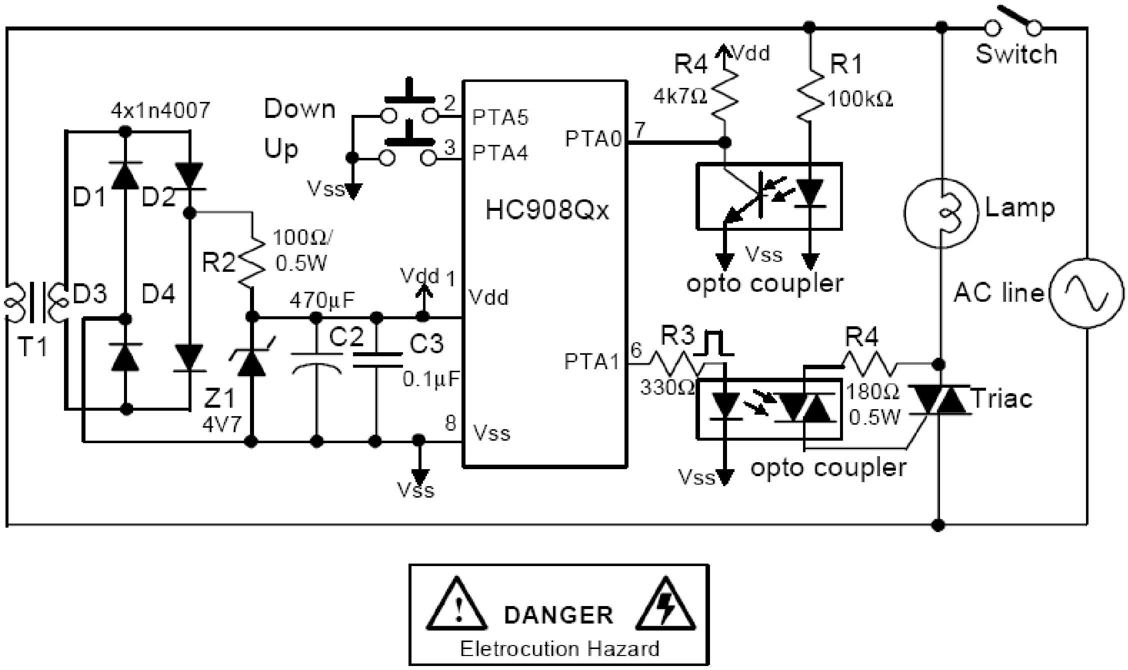


Figure 6. Isolated Dimmer with HC908Q Family

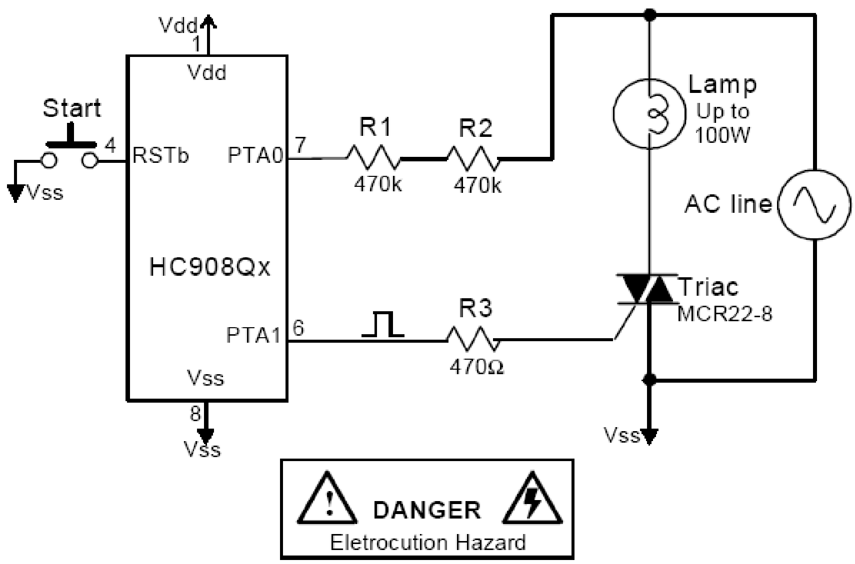


Figure 7. Lamp Timer with HC9098Q Family

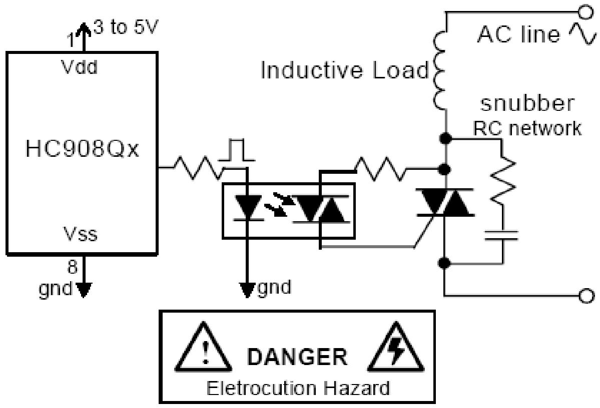


Figure 8. Switching Inductive Loads with HC908Q Family

Software Description

Two software codes were developed for this application note. The first one implements a lamp dimmer; the second one was developed for an application where a lamp is turned on for a specific amount of time.

Lamp Dimmer Source Code

For the lamp dimmer source code, the MCU controls the lamp brightness by adjusting the conduction angle with the timer modulus as illustrated in Figure 9.

The code starts initializing configuration and timer registers, defining ports, and clearing variables and accumulators. The initial timer value is set to have almost the maximum brightness adjusting the constants *InitTMODH* and *InitTMODL.*

PTA0 senses the zero-crossing detection circuit. Each time a positive or negative edge is detected, the timer starts to count until the timer module value (composed by *TMODH:TMODL*) is reached.

When PTA0 recognizes a positive edge, the MCU verifies PTA5 and PTA4.

If PTA5 is in low level, the routine increments the timer modulus value if it is below the upper limit. PTA4 decrements the timer modulus value if it is above the lower limit when applied a low level. When a timer overflow occurs, PTA1 generates a pulse train triggering the triac.

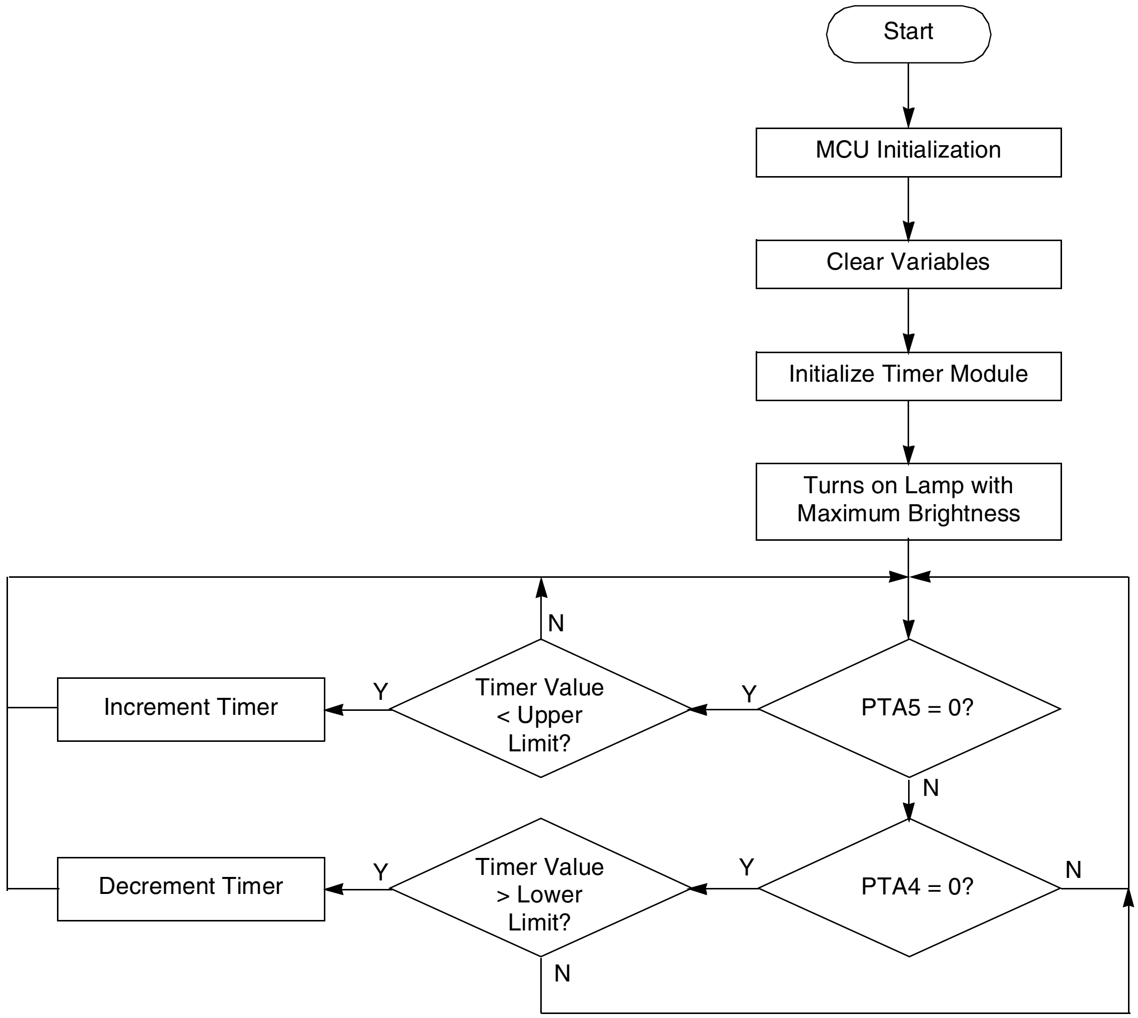


Figure 9. Flowchart for Lamp Dimmer Source Code

Lamp Timer Source Code

Figure 10 shows the flowchart for a lamp timer.

The code starts by initializing configuration and timer registers, defining ports, and clearing variables and accumulators.

PTA0 senses the zero-crossing detection circuit. Each time a positive or negative edge is detected the timer starts to count until the timer modulus value (composed by *TMODH:TMODL*) is reached. When a timer overflow occurs, PTA1 generates a pulse triggering the triac.

A 2-byte counter is incremented at each zero-crossing of 60 Hz (or 50 Hz if it is used) and compared to *CntHcmp* and *CntLcmp* constants. These constants may also be changed if the user desires to increase or decrease the timer. A simple formula can be used:

$$CntHcmp : CntLcmp = \frac{t}{1/f} \qquad \text{Equation (1)}$$

Where: t = desired timer, [s]

f = line frequency, [Hz]

CntHcmp:CntLcmp = constant values, [decimal]

The user must remember that for a 2-byte counter, the maximum time will be approximately 18 seconds for 60-Hz and 21 seconds for 50-Hz line frequency, according to the equation. Software timing techniques can be used to extend this delay time.

When the defined time is reached, the MCU enters stop mode to minimize current consumption.

The lamp timer turns on again after a reset.

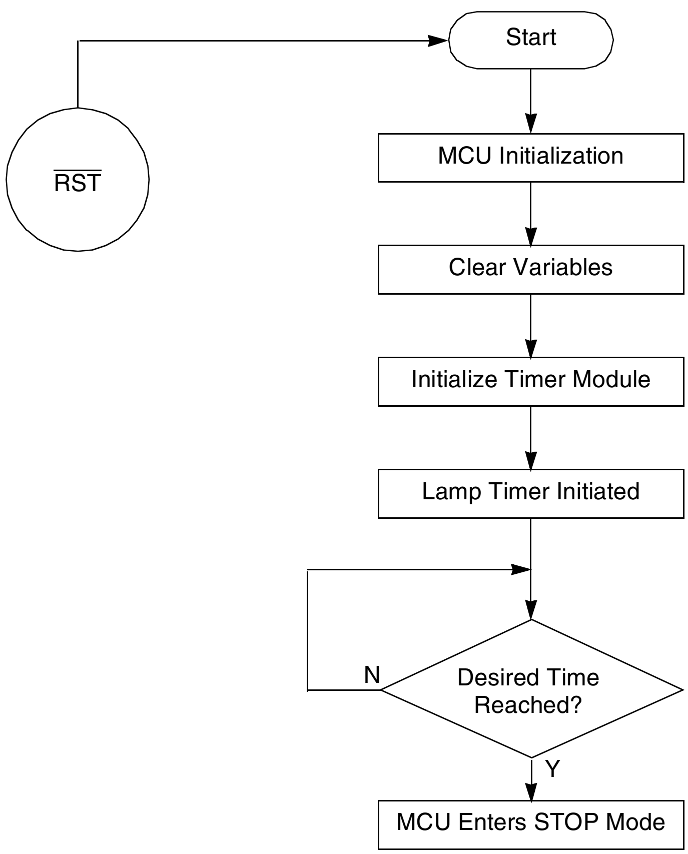


Figure 10. Flowchart for Lamp Timer

```
;*******************************************************************************************
;* Title: dimmer.asm                                     Copyright (c) Freescale 2004
;*******************************************************************************************
;* Author: Marcus Espindola - Freescale SPS/BSTC
;*
;* Description: Implementing a Lamp Dimmer with HC908Qx MCU.
;*
;* Documentation: HC908QY4 Data Sheet (MC68HC908QY4/D) for register and bit explanations
;*
;* Include Files: dimmer.equ, MC68HC908QT4.equ
;*
;* Assembler: P&E Microcomputer Systems - CASM for HC08
;*            Metrowerks CodeWarrior Compiler for HC08 V-5.0.17
;*
;* Revision History:
;* Rev #      Date       Who         Comments
;* -----    -----------  ---------   ---------------------------------------------------------
;* 0.3      10-Sep-04    Espindola   Adjusted timer values according to circuit
;* 0.2      15-May-04    Espindola   Included 1 minute timer
;* 0.1      09-Feb-04    Espindola   Initial data entry
;*******************************************************************************************
;*******************************************************************************************
;* Freescale reserves the right to make changes without further notice to any product
;* herein to improve reliability, function, or design. Freescale does not assume any
;* liability arising out of the application or use of any product, circuit, or software
;* described herein; neither does it convey any license under its patent rights nor the
;* rights of others. Freescale products are not designed, intended, or authorized for
;* use as components in systems intended for surgical implant into the body, or other
;* applications intended to support life, or for any other application in which the
;* failure of the Freescale product could create a situation where personal injury or
;* death may occur. Should Buyer purchase or use Freescale products for any such
;* intended or unauthorized application, Buyer shall indemnify and hold Freescale and
;* its officers, employees, subsidiaries, affiliates, and distributors harmless against
;* all claims, costs, damages, and expenses, and reasonable attorney fees arising out
;* of, directly or indirectly, any claim of personal injury or death associated with
;* such unintended or unauthorized use, even if such claim alleges that Freescale was
;* negligent regarding the design or manufacture of the part.
;*
;* Freescale is a registered trademark of Freescale Semiconductor, Inc.
;*******************************************************************************************


;*******************************************************************************************
;* Equates and Data Table Includes
;*******************************************************************************************

            include 'MC68HC908QT4.equ'    ; For the QT1, QT2, QT4, QY1, QY2, QY4

           org $FFC0

trim_val:  DC.B $FF      ; here we set the FLASH trim to a default value.
                         ; DO NOT change this value, as the trim will not be
                         ; automatically calibrated by the programming interface if
                         ; this value is anything other than $FF

            org   RamStart

;*******************************************************************************************
;* Constants and Variables for this file
;*******************************************************************************************

            include 'dimmer.equ'
```

```
;**************************************************************************************
;* SUBROUTINES
;* This part includes subroutines
;**************************************************************************************

            org   FlashStart


;**************************************************************************************
;* Table used for timer value after zero-crossing detection
;* This table uses indexed addressing mode
;**************************************************************************************

LSBTimer:   dc.b  $73;
            dc.b  $90;
            dc.b  $AD;
            dc.b  $CA;
            dc.b  $E7;
            dc.b  $04;
            dc.b  $21;
            dc.b  $3E;
            dc.b  $5B;
            dc.b  $78;
            dc.b  $95;
            dc.b  $B2;
            dc.b  $CF;
            dc.b  $EC;
            dc.b  $09;
            dc.b  $26;
            dc.b  $43;
            dc.b  $60;
            dc.b  $7D;
            dc.b  $9A;
            dc.b  $B7;
            dc.b  $D4;
            dc.b  $F1;
            dc.b  $0E;
            dc.b  $2B;
            dc.b  $48;
            dc.b  $65;
            dc.b  $82;
            dc.b  $9F;
            dc.b  $BC;
            dc.b  $D9;
            dc.b  $F6;

MSBTimer:   dc.b  $03;
            dc.b  $04;
            dc.b  $05;
            dc.b  $06;
            dc.b  $07;
            dc.b  $09;
            dc.b  $0A;
            dc.b  $0B;
            dc.b  $0C;
            dc.b  $0D;
            dc.b  $0E;
            dc.b  $0F;
            dc.b  $10;
            dc.b  $11;
            dc.b  $13;
            dc.b  $14;
```

```
            dc.b  $15;
            dc.b  $16;
            dc.b  $17;
            dc.b  $18;
            dc.b  $19;
            DC.B  $1A;
            dc.b  $1B;
            dc.b  $1D;
            dc.b  $1E;
            dc.b  $1F;
            dc.b  $20;
            dc.b  $21;
            dc.b  $22;
            dc.b  $23;
            dc.b  $24;
            dc.b  $25;

InitTimer:  mov   #initTim,TSC ;Timer - Cleared + Stopped.

            mov   #InitTMODH,TMODH ;Set max. brightness
            mov   #InitTMODL,TMODL ;after we start the timer.

            bra   Skip

;Subroutine for Thyristor gate control

Gate:       lda   #GateVal    ;Gate pulse duration
loop:       bset  PTA1,PTA
            nop
            bclr  PTA1,PTA
            dbnza loop

            jmp   Skip

;Subroutine for Timer Overflow

TOverflow:  nop
            nop
            brclr TOF,TSC,TOverflow ;Wait for Timer Overflow

            lda   TSC
            and   #TSCClr
            sta   TSC         ;Clear TOF bit

            mov   #initTim,TSC ;STOP and RESET Counter

            bra   Skip

;Subroutine for Dimmer

IncTimer:   incx
            cpx   #IncTcomp
            bhi   Escape

            lda   MSBTimer,x
            sta   TMODH
            lda   LSBTimer,x
            sta   TMODL

            bra   Skip

Escape:     ldx   #IncTcomp
```

```
            lda   MSBTimer,x
            sta   TMODH
            lda   LSBTimer,x
            sta   TMODL

            bra   Skip

DecTimer:   decx
            cpx   #DecTcomp
            blo   EscapeDec

            lda   MSBTimer,x
            sta   TMODH
            lda   LSBTimer,x
            sta   TMODL

            bra   Skip

EscapeDec:  ldx   #DecTcomp

            lda   MSBTimer,x
            sta   TMODH
            lda   LSBTimer,x
            sta   TMODL

            bra   Skip

Delay:      lda   #Delval
Xloop:      brn   *
            brn   *
            dbnza Xloop

Skip:       rts


;*******************************************************************************************
;* Main Init
;* This is the point where code starts executing after a RESET.
;*******************************************************************************************

main:
            mov   #initCfg1,CONFIG1 ;Set config1 register
                                  ;(LVI and COP disabled)

            mov   #initCfg2,CONFIG2 ;set MCU to internal oscillator, IRQ enabled

            mov   #InitDDRA,DDRA ;PTA0 -> Zero Crossing detection
            bset  DDRA1,DDRA    ;PTA1 -> Pulses on Thyristor gate
                                ;PTA2 as IRQb -> Turns on dimmer
                                ;PTA3 as RSTb -> Turns on 1-minute timer
                                ;PTA4 -> Dec. lamp brightness
                                ;PTA5 -> Inc. lamp brightness
            bset  PTAPUE4,PTAPUE
            bset  PTAPUE5,PTAPUE

            clr   Counter1
            clr   Counter2

            clrh
            ldx   #Xval

            jsr   InitTimer     ;Goes config Timer
            cli                 ;Allow interrupts to happen
```

```
Waitpta0:   nop
            brclr PTA0,PTA,Waitpta0  ;Wait for a edge on PTA0 (Zero crossing)

            brclr  PTA5,PTA,IncT ;Inc timer if PTA5 is clear
            brclr  PTA4,PTA,DecT ;Dec timer if PTA4 is clear

Next:       mov   #StartTim,TSC  ;Start the timer

            jsr   TOverflow   ;Go to Timer Overflow subroutine

            jsr   Gate        ;Go to Gate subroutine

Waitpta:    nop
            brset  PTA0,PTA,Waitpta  ;Wait for a edge on PTA0 (Zero crossing)

Next1:      mov   #StartTim,TSC ;Start the timer

            jsr   TOverflow   ;Go to Timer Overflow subroutine

            jsr   Gate        ;Go to Gate subroutine

            bra   Waitpta0

IncT:       jsr   Delay
            cpx   #IncTcomp
            beq   Next
            jsr   IncTimer
            bra   Next

DecT:       jsr   Delay
            cpx   #DecTcomp
            beq   Next
            jsr   DecTimer
            bra   Next

;**** Interrupt Vectors ***********

            org    $FFFE
            dcw    main


END
```

```
;*******************************************************************************
;* Title: timer.asm                                     Copyright (c) Freescale 2004
;*******************************************************************************
;* Author: Marcus Espindola - Freescale SPS/BSTC
;*
;* Description: Implementing a Lamp Dimmer with HC908Qx MCU.
;*
;* Documentation: HC908QY4 Data Sheet (MC68HC908QY4/D) for register and bit explanations
;*
;* Include Files: dimmer.equ, MC68HC908QT4.equ
;*
;* Assembler: P&E Microcomputer Systems - CASM for HC08
;*            Metrowerks CodeWarrior Compiler for HC08 V-5.0.17
;*
;* Revision History:
;* Rev #     Date        Who         Comments
;* -----   -----------  ---------   ----------------------------------------------------
;* 0.3      10-Sep-04   Espindola   Adjusted timer values according to circuit
;* 0.2      15-May-04   Espindola   Included 1 minute timer
;* 0.1      09-Feb-04   Espindola   Initial data entry
;*******************************************************************************
;*******************************************************************************
;* Freescale reserves the right to make changes without further notice to any product
;* herein to improve reliability, function, or design. Freescale does not assume any
;* liability arising out of the application or use of any product, circuit, or software
;* described herein; neither does it convey any license under its patent rights nor the
;* rights of others. Freescale products are not designed, intended, or authorized for
;* use as components in systems intended for surgical implant into the body, or other
;* applications intended to support life, or for any other application in which the
;* failure of the Freescale product could create a situation where personal injury or
;* death may occur. Should Buyer purchase or use Freescale products for any such
;* intended or unauthorized application, Buyer shall indemnify and hold Freescale and
;* its officers, employees, subsidiaries, affiliates, and distributors harmless against
;* all claims, costs, damages, and expenses, and reasonable attorney fees arising out
;* of, directly or indirectly, any claim of personal injury or death associated with
;* such unintended or unauthorized use, even if such claim alleges that Freescale was
;* negligent regarding the design or manufacture of the part.
;*
;* Freescale is a registered trademark of Freescale Semiconductor, Inc.
;*******************************************************************************

;*******************************************************************************
;* Equates and Data Table Includes
;*******************************************************************************

            include 'MC68HC908QT4.equ'    ; For the QT1, QT2, QT4, QY1, QY2, QY4

           org $FFC0

trim_val:  DC.B $FF      ; here we set the FLASH trim to a default value.
                         ; DO NOT change this value, as the trim will not be
                         ; automatically calibrated by the programming interface if
                         ; this value is anything other than $FF

            org   RamStart

;*******************************************************************************
;* Constants and Variables for this file
;*******************************************************************************

            include 'dimmer.equ'
```

```
;****************************************************************************************
;* SUBROUTINES
;* This part includes subroutines
;****************************************************************************************

            org   FlashStart

InitTimer:  mov   #initTim,TSC ;Timer - Cleared + Stopped.

            mov   #InitTMODH,TMODH ;Set max. brightness
            mov   #InitTMODL,TMODL ;after we start the timer.

            bra   Skip

;Subroutine for Thyristor gate control

Gate:       lda   #GateVal    ;Gate pulse duration
loop:       bset  PTA1,PTA
            nop
            bclr  PTA1,PTA
            dbnza loop

            jmp   Skip

;Subroutine for Timer Overflow

TOverflow:  nop
            nop
            brclr TOF,TSC,TOverflow ;Wait for Timer Overflow

            lda   TSC
            and   #TSCClr
            sta   TSC         ;Clear TOF bit

            mov   #initTim,TSC ;STOP and RESET Counter

            bra   Skip

Skip:       rts


;****************************************************************************************
;* Main Init
;* This is the point where code starts executing after a RESET.
;****************************************************************************************

main:
            mov   #initCfg1,CONFIG1 ;Set config1 register
                              ;(LVI and COP disabled)

            mov   #initCfg2,CONFIG2 ;set MCU to internal oscillator, IRQ enabled

            mov   #InitDDRA,DDRA ;PTA0 -> Zero Crossing detection
            bset  DDRA1,DDRA  ;PTA1 -> Pulses on Thyristor gate
                              ;PTA3 as RSTb -> Turns on 1-minute timer

            clr   Counter1
            clr   Counter2

            clrh
            clrx
```

```
            jsr   InitTimer   ;Goes config Timer
            cli               ;Allow interrupts to happen

ZeroDetec:  nop
            brclr PTA0,PTA,ZeroDetec ;Wait for a edge on PTA0 (Zero crossing)

            mov   #StartTim,TSC  ;Start the timer

            jsr   TOverflow   ;Go to Timer Overflow subroutine

            jsr   Gate        ;Go to Gate subroutine

ZeroDetect: nop
            brset  PTA0,PTA,ZeroDetect ;Wait for a edge on PTA0 (Zero crossing)

            mov   #StartTim,TSC ;Start the timer

            jsr   TOverflow   ;Go to Timer Overflow subroutine

            jsr   Gate        ;Go to Gate subroutine

            inc   Counter1    ;Increment 1st byte Counter for charge time OVF period
            lda   #CntLcmp
            cbeq  Counter1,Count1

            bra   ZeroDetec

Count1:     inc   Counter2    ;Increment 2nd byte Counter for charge time OVF period
            lda   #CntHcmp
            cbeq  Counter2,Out

            bra   ZeroDetec

Out:        clr   Counter1
            clr   Counter2
            stop

;**** Interrupt Vectors ***********

            org    $FFFE
            dcw    main

END
```

```
;*******************************************************************************
;* Title: dimmer.equ                                      Copyright (c) Freescale 2004
;*******************************************************************************
;* Author: Marcus Espindola - Freescale SPS/BSTC
;*
;* Description: Constants and variables definitions for MC68HC908QY4 and MC68HC908QT4.
;*
;* Documentation: HC908QY4 Data Sheet (MC68HC908QY4/D) for register and bit explanations
;*
;* Include Files:
;*
;* Assembler: P&E Microcomputer Systems - CASM for HC08
;*            Metrowerks CodeWarrior Compiler for HC08 V-5.0.17
;*
;* Revision History:
;* Rev #      Date       Who         Comments
;* -----   -----------  ---------   ---------------------------------------------
;* 0.1      09-Feb-04   Espindola   Initial data entry
;*******************************************************************************
;*******************************************************************************
;* Freescale reserves the right to make changes without further notice to any product
;* herein to improve reliability, function, or design. Freescale does not assume any
;* liability arising out of the application or use of any product, circuit, or software
;* described herein; neither does it convey any license under its patent rights nor the
;* rights of others. Freescale products are not designed, intended, or authorized for
;* use as components in systems intended for surgical implant into the body, or other
;* applications intended to support life, or for any other application in which the
;* failure of the Freescale product could create a situation where personal injury or
;* death may occur. Should Buyer purchase or use Freescale products for any such
;* intended or unauthorized application, Buyer shall indemnify and hold Freescale and
;* its officers, employees, subsidiaries, affiliates, and distributors harmless against
;* all claims, costs, damages, and expenses, and reasonable attorney fees arising out
;* of, directly or indirectly, any claim of personal injury or death associated with
;* such unintended or unauthorized use, even if such claim alleges that Freescale was
;* negligent regarding the design or manufacture of the part.
;*
;* Freescale is a registered trademark of Freescale Semiconductor, Inc.
;*******************************************************************************

;*******************************************************************************
;* Constants and Variables for this file
;*******************************************************************************

initCfg1:   equ   %00010011   ;Config1 Register value
;                  ||||||||   CONFIG1 is a write once register
;                  |||||||+-COPD     - 1 disable COP Watchdog
;                  ||||||+--STOP     - 1 enable STOP instruction
;                  |||||+---SSREC    - 0 4096 cycle STOP recovery
;                  ||||+----LVI5OR3  - 0 set LVI for 3V system
;                  |||+-----LVIPWRD  - 1 disable power to LVI system
;                  ||+------LVIRSTD  - 0 enable reset on LVI trip
;                  |+-------LVISTOP  - 0 disable LVI in STOP mode
;                  +--------COPRS    - 0 long COP timeout

initCfg2:   equ   %01000001   ;Config2 Register value
;                  ||||||||   CONFIG2 is a write once register
;                  |||||||+-RSTEN    - 1 Reset function active in pin
;                  ||||||+--R        - 0 Reserved bit
;                  |||||+---R        - 0 Reserved bit
;                  ||||+----OSCOPT0  - 0 Set oscillator option as internal
;                  |||+-----OSCOPT1  - 0 Set oscillator option as internal
;                  ||+------R        - 0 Reserved bit
```

```
;                  |+-------IRQEN   - 1 enable IRQ function
;                  +--------IRQPUD  - 0 Internal pullup connect IRQ and VDD

initTim:    equ   %00110001   ;Timer Status and control Reg. value
;                  |||||||| TIM Status and Control Register
;                  ||||||+-PS0      - 1 Prescaler select bit
;                  |||||+--PS1      - 0 Prescaler select bit
;                  ||||+---PS2      - 0 Tim clock source int. bus
;                  |||+----0        - 0
;                  ||+-----TRST     - 1 TIM reset bit
;                  |+------TSTOP    - 1 TIM counter stopped
;                  |+-------TOIE    - 0 disable TIM overflow interrupts
;                  +--------TOF     - 0 TIM overflow flag bit

StartTim:   equ   %00000001   ;Timer Status and control Reg. value
;                  ||||||||   TIM Status and Control Register
;                  ||||||+-PS0      - 1 Prescaler select bit
;                  |||||+--PS1      - 0 Prescaler select bit
;                  ||||+---PS2      - 0 Tim clock source int. bus
;                  |||+----0        - 0
;                  ||+-----TRST     - 0 TIM reset bit
;                  |+------TSTOP    - 0 TIM counter started
;                  |+-------TOIE    - 0 disable TIM overflow interrupts
;                  +--------TOF     - 0 TIM overflow flag bit

InitDDRA:   equ   %00000010   ;PTA0 -> Zero Crossing detection
                              ;PTA1 -> Pulses on Thyristor gate
                              ;PTA2 -> Increment Dimmer
                              ;PTA4 -> Decrement Dimmer
                              ;PTA5 -> Turns on 1-minute timer.

InitIRQ:    equ   $00         ;IRQ configuration

InitTMODH:  equ   $00         ;Set max. brightness
InitTMODL:  equ   $FF         ;after we start the timer.

GateVal:    equ   $50         ;Gate pulse duration

TSCClr:     equ   $7F         ;Value to clear TOF bit on TSC register

Counter1:   rmb   1
Counter2:   rmb   1

IncTcomp:   equ   $1F
DecTcomp:   equ   $01

CntLcmp:    equ   $00
CntHcmp:    equ   $0E

Delval:     equ   $FF
Xval:       equ   $01
```

This page is intentionally blank.

How to Reach Us:

USA/Europe/Locations not listed:
Freescale Semiconductor Literature Distribution
P.O. Box 5405, Denver, Colorado 80217
1-800-521-6274 or 480-768-2130

Japan:
Freescale Semiconductor Japan Ltd.
SPS, Technical Information Center
3-20-1, Minami-Azabu
Minato-ku
Tokyo 106-8573, Japan
81-3-3440-3569

Asia/Pacific:
Freescale Semiconductor H.K. Ltd.
2 Dai King Street
Tai Po Industrial Estate
Tai Po, N.T. Hong Kong
852-26668334

Learn More:
For more information about Freescale Semiconductor products, please visit
http://www.freescale.com