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Application Note

CSI to SPI Peripheral Communication in V850ES Microcontrollers

Document no. U18518EU1V0UM00

Contents

1. INTRODUCTION

The purpose of this document is to provide simple examples that will help you better understand functionality of the peripherals included in the NEC Electronics V850ES™ MCU.

This document includes

- Description of peripheral features
- Example program descriptions and specifications
- Software flowcharts
- Applilet reference drivers
- Demonstration platforms used
- Hardware block diagram
- Software modules

Applilet is a software tool that generates driver code for the peripherals. It is a convenient means to generate code for the on-chip peripherals for quick evaluation.

For more information about V850ES MCUs or the Applilet code generator, refer to their respective user's manuals.

2. NEC ELECTRONICS CSI TO SPI COMMUNICATION

The NEC Electronics clocked serial I/O (CSI) peripheral communication method, also known as 3-wire serial I/O, uses three lines: serial clock (SCK), data input (SI) and data output (SO). In some cases, one additional line is used as a handshake (HS) between master and slave for simultaneous transmission and reception. The data transmission and reception is done in synchronization with the SCK clock, making communication simple and straightforward. Most NEC Electronics MCUs implement one or more channels of CSI peripheral hardware.

An alternate method to the CSI interface is the serial peripheral interface (SPI). The SPI also uses SCK, SI, and SO. To support master-slave configuration, the SPI also uses a slave-select (SS_B) signal to select a communicating peripheral. SPI data transmission and reception is also done in synchronization with the clock.

The implementation, clocking, and control methods for NEC Electronics' CSI and SPI are both similar and different in hardware. This document will review both and provide reference examples so that the two communication methods can be used interchangeably, without additional hardware or modification.

Most NEC Electronics MCUs incorporate one or more channels of CSI peripheral, for easy interconnection of devices. This type of interface can also be configured to connect to other devices supporting a 3-wire clocked serial interface.

In 3-wire serial I/O communication, data is transmitted or received in eight-bit units; some NEC Electronics MCUs allow transmission in 16-bit units. Each bit of data is transmitted or received in synchronization with the serial clock. One side of the communication controls the clock line, so this is a master-slave configuration, typically with one master and one slave.

If only one slave device drives data back to the master, multiple slaves receiving data can be supported without additional hardware. If multiple slaves need to drive data back to the master, additional chip select lines and logic must be implemented.

In communication situations where data is sent in both directions, transmission time can be shortened using CSI, since transmit and receive transfers can be executed simultaneously.

2.1 NEC Electronics CSI Communication

The clocked serial interface (CSI) peripheral implemented for the V850ES devices typically offer the following features. Many devices offer multiple channels of CSI units. The following is a list of features offered for the 32-bit µPD70F3318 MCU, a device in the V850ES/KJ1+ product line. Most NEC Electronics 32-bit MCUs offer similar CSI features.

- Maximum transfer speed: up to 5 Mbps
- Selectable master and slave modes
- Transmission data length: 8 or 16 bits
- MSB/LSB-first selection option for data transfer
- Multiple clock signals
- 3-wire type (three channels of CSI as implemented for the µPD70F3318Y MCU)
    - SO0n: serial transfer data output, where n = 0–2
    - SI0n: serial receive data input, where n = 0–2
    - SCK0n_B: serial clock, where n = 0–2
- Transmission/reception completion interrupt
- Selectable transmit and receive mode or receive-only mode
- Two transmission buffer registers and two reception buffer registers
- Selectable single transfer mode or continuous transfer mode

When the CSI peripheral is not used, the SCK, SO, and SI I/O pins can be used as port pins. The CSI units are configured using mode registers, control registers, configuration registers, and dedicated hardware logic.

Table 1. Description of Registers

Register Type	Register Name	Symbol	Functional Description
Control	CSI Mode (8-bit)	CSIM0n	Specifies CSI operation
	Clock Selection	CSICn	Controls CSI serial transfer operation
Configuration	Shift (8-, 16-bit)	SIO0n/SIO0nL	Converts parallel data to serial data
	Receive Buffer (8-, 16-bit)	SIRBn/SIRBnL	Buffer register for receive data
	Transmit Buffer (8-, 16-bit)	SOTBn/SOTBnL	Buffer register for transmit data
	Initial Transmit Buffer	SOTBFn/SOTBFnL	Stores initial data in continuous transfer mode
Configuration Hardware Logic	Clock Select Logic		Selects the serial clock to be used
	Serial Clock Counter		Controls the serial clock to the Shift Register
	Interrupt Controller		Controls interrupt request timing

The **CSI Mode** register configures the CSI unit for:

- Enabled or disabled operation
- Receive-only mode or transmit and receive mode
- 8- or 16-bit data length
- Most significant bit (MSB) or least significant bit (LSB) first
- Single or continuous transfer

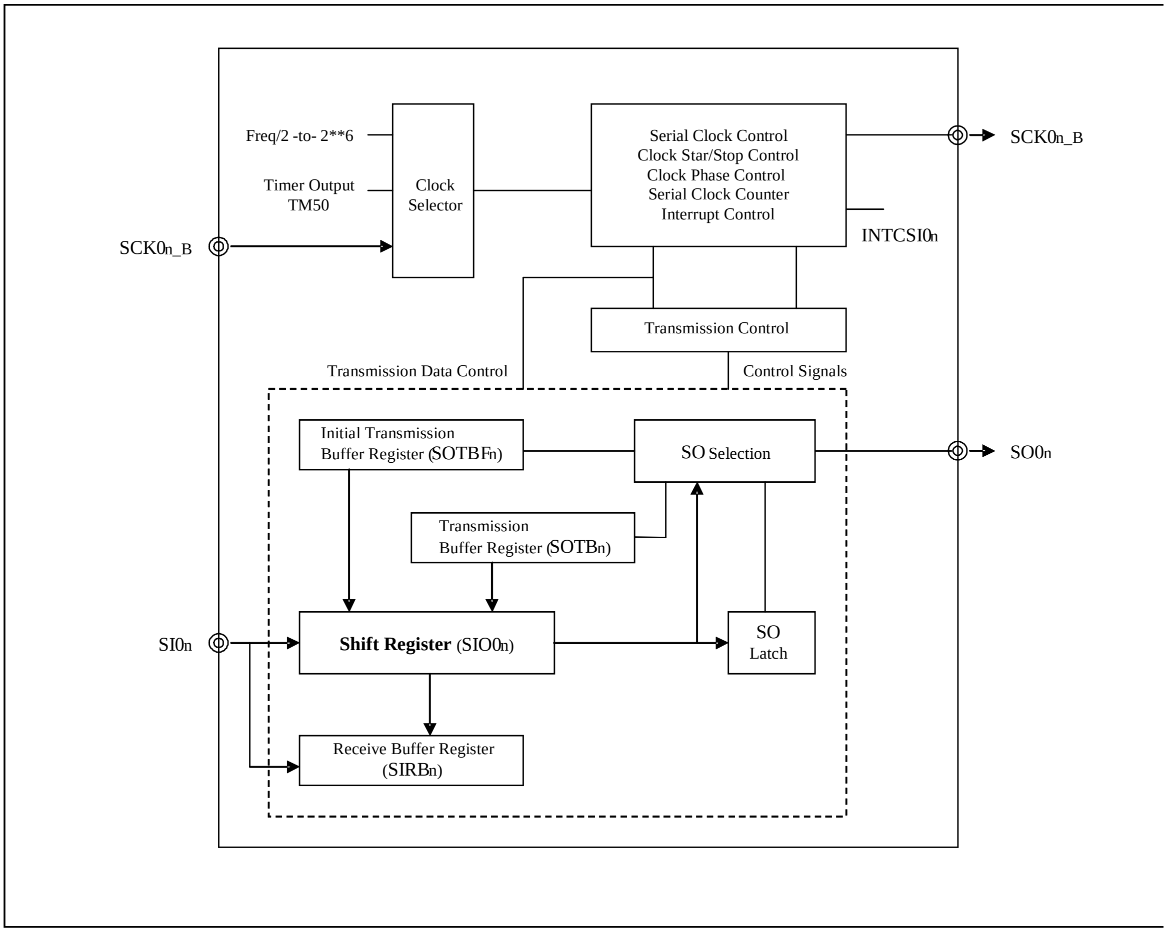
Clock selection and CSI transfer operation depends on:

- Whether a positive or negative edge of the clock is used for the data capture strobe (clock polarity)
- Whether the first edge of clock is used for the ata capture or data drive strobe (clock phase)

For example, the timing diagram shown in Figure 2 illustrates a positive-edge data capture, with the first edge of clock used for data capture and the trailing edge for data drive strobe. See type 4 in Figure 3.

It is important to note that the master unit controls the serial clock. If the first edge of the serial clock is used for the data capture strobe, the slave unit must be ready with data (driving data) before the first edge of the serial clock. Typically, in this case, the **Chip Select** signal is used to indicate the start of transmission from the master unit.

Figure 1. CSI Operation



The second method of data transfer is to use the first edge of the serial clock as the data drive strobe and the second edge for the data capture strobe. In this case, the first edge of the serial clock is used to indicate start of transmission from the master unit.

For NEC Electronics MCUs, the **Clock Selection Register**, CSICn, specifies CSI transfer operation.

- CKPn selects clock polarity.
- DAPn specifies whether the first edge of the serial clock is data capture or data drive.

The slave unit, whether it is another MCU or a peripheral device such as a serial EEPROM, must provide interface logic to support any one of the above type 1 through 4 clocking methods. The master unit must be configured such that it can communicate with a certain type of clocking method used by the slave unit.

Figure 2. Positive-Edge Data Capture

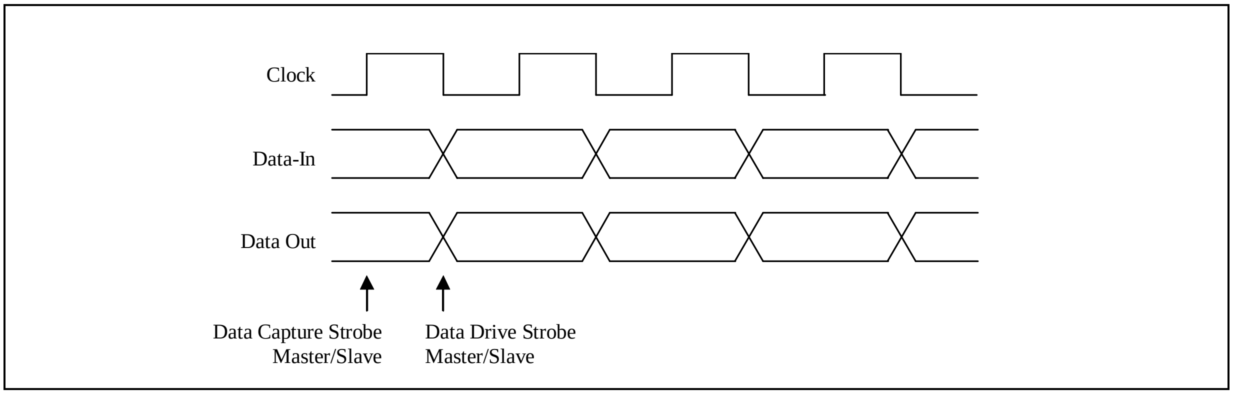
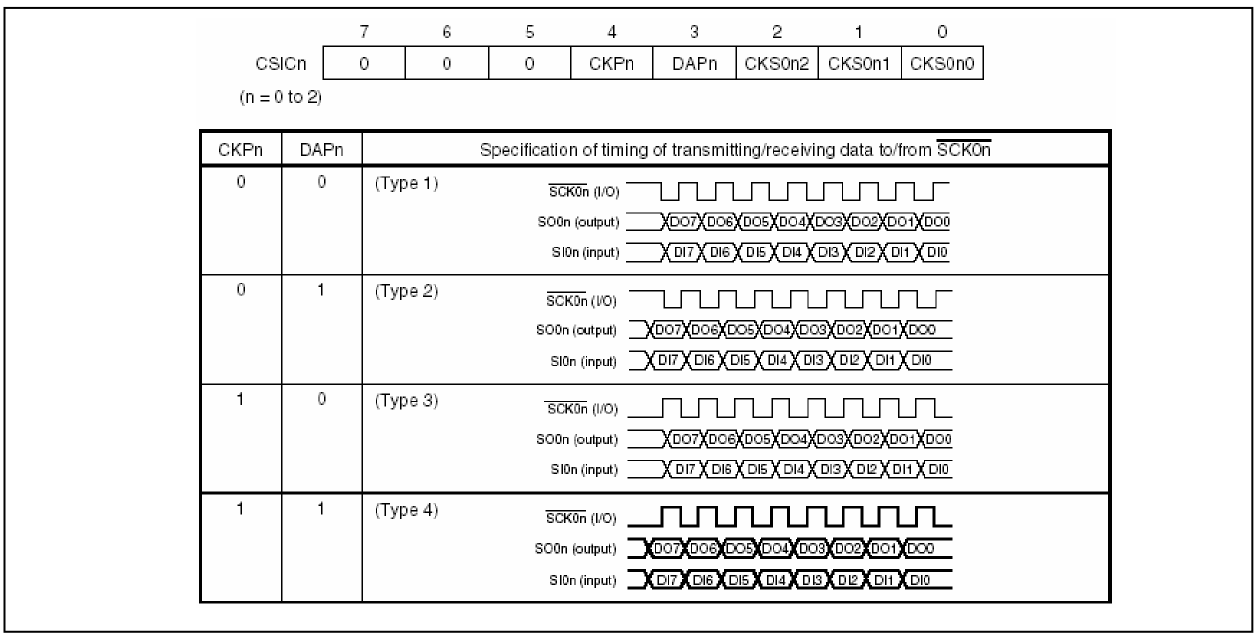


Figure 3. Timing Specifications for Transmit and Receive Operations



	7	6	5	4	3	2	1	0
CSICn (n = 0 to 2)	0	0	0	CKPn	DAPn	CKS0n2	CKS0n1	CKS0n0

CKPn	DAPn	Specification of timing of transmitting/receiving data to/from $\overline{SCK0n}$
0	0	(Type 1) $\overline{SCK0n}$ (I/O), SO0n (output): DO7 DO6 DO5 DO4 DO3 DO2 DO1 DO0, SI0n (input): DI7 DI6 DI5 DI4 DI3 DI2 DI1 DI0
0	1	(Type 2) $\overline{SCK0n}$ (I/O), SO0n (output): DO7 DO6 DO5 DO4 DO3 DO2 DO1 DO0, SI0n (input): DI7 DI6 DI5 DI4 DI3 DI2 DI1 DI0
1	0	(Type 3) $\overline{SCK0n}$ (I/O), SO0n (output): DO7 DO6 DO5 DO4 DO3 DO2 DO1 DO0, SI0n (input): DI7 DI6 DI5 DI4 DI3 DI2 DI1 DI0
1	1	(Type 4) $\overline{SCK0n}$ (I/O), SO0n (output): DO7 DO6 DO5 DO4 DO3 DO2 DO1 DO0, SI0n (input): DI7 DI6 DI5 DI4 DI3 DI2 DI1 DI0

2.2 SPI Communication

A typical MCU master with an SPI unit takes a form similar to NEC Electronics CSI units (Figure 4).

The **SPI Mode Control Register** specifies the transfer operation (Figure 5). When CPHA = 0, the first edge of SCK is the data capture strobe for the first bit. Therefore, the slave unit must begin driving its data before the first edge of SCK. The falling edge of SS_B (slave Chip Select) is used to indicate the start of transmission. The SS_B must toggle high and then low between transmissions.

When CPHA = 1, the master begin driving data at the first edge of SCK. Therefore, the slave unit uses the first edge of SCK as start of transmission signal. In this clocking mode, the SS_B can remain low (active chip select state) between transmissions. This clocking method may be preferable for one master and one slave configuration.

Figure 4. SPI Operation

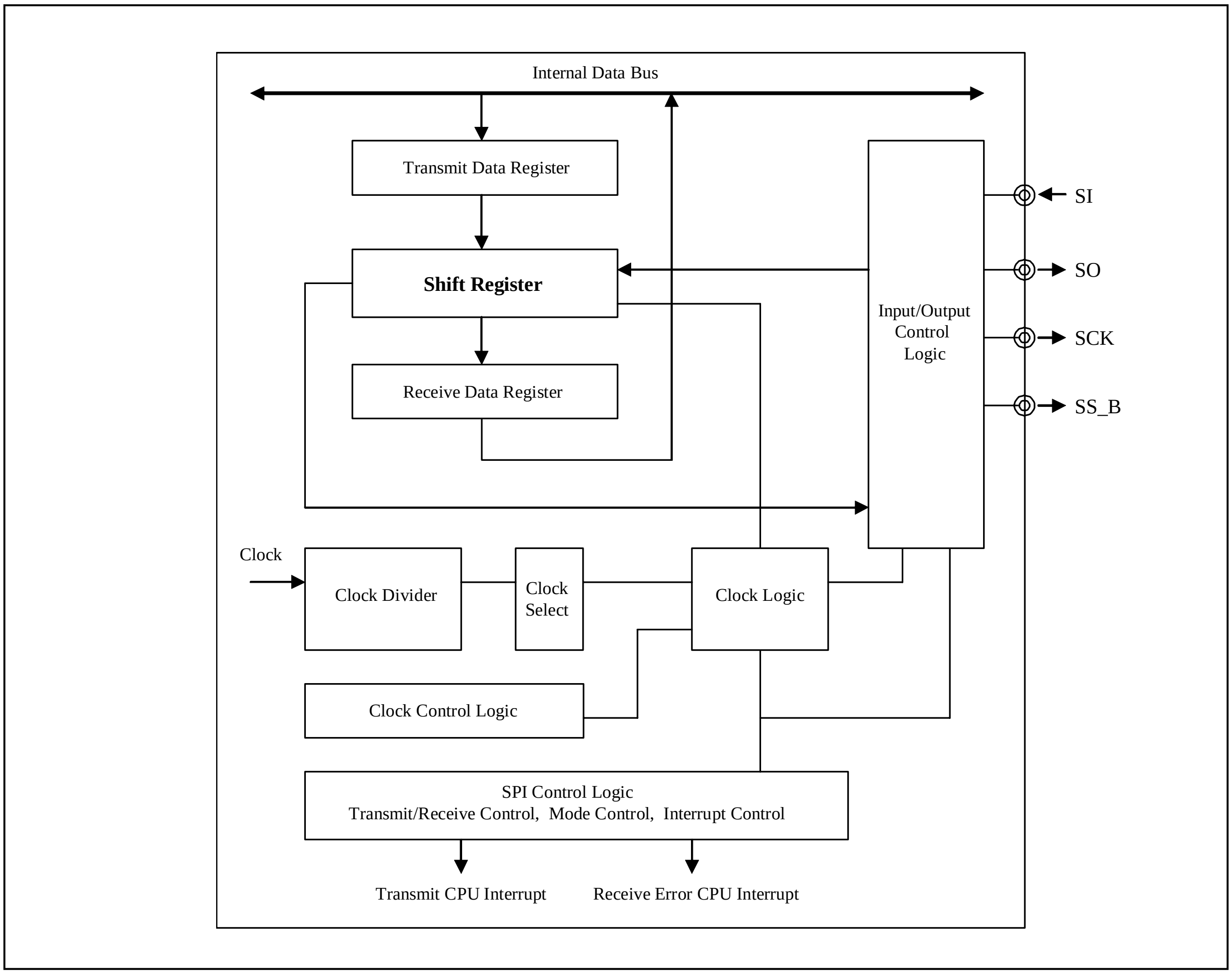
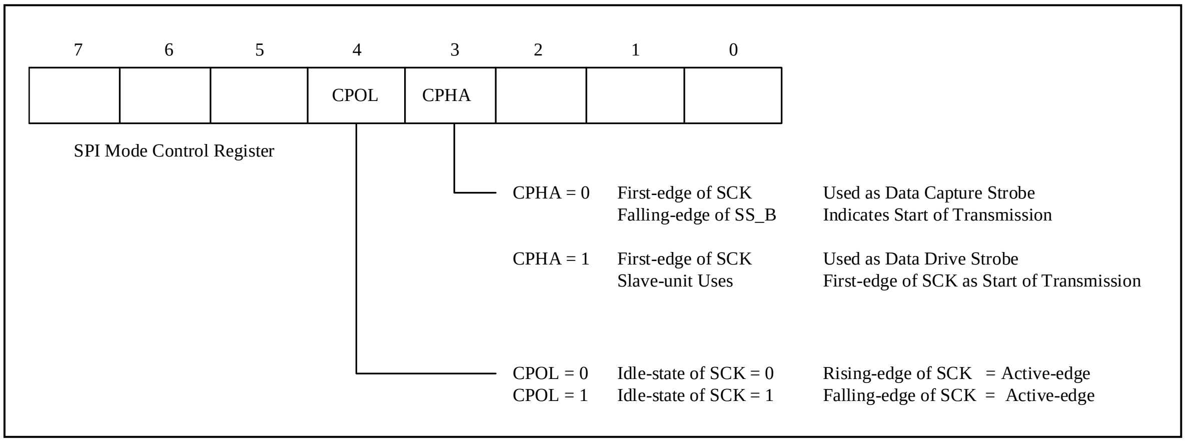


Figure 5. SPI Mode Control Register



2.3 Comparison of NEC Electronics CSI and SPI Transfer Operations

The NEC Electronics CSI unit has a **Clock Selection Register** (CSICn), which specifies clocking method using the CKPn and DAPn bits. The SPI unit has an **SPI Control Register**, which specifies clocking method using the CPOL and CPHA bits. Table 2 shows a comparison of NEC Electronics CSI clocking methods and those of the SPI.

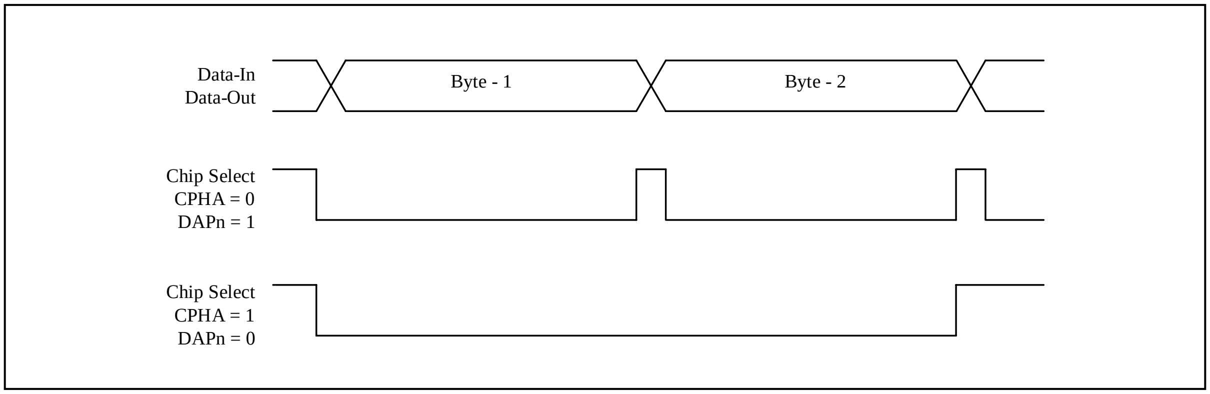
Table 2. CSI and SPI Clocking Methods

NEC Electronics CSI Clocking Method				SPI Clocking Method		
CKPn	**DAPn**	**Clocking Type Descriptions**		**CPOL**	**CPHA**	**Clocking Type Descriptions**
0	0	Type 1 clocking method		1	1	Idle state clock = 1
		Idle state clock = 1				First edge SCK is data drive strobe
		First edge SCK is data drive strobe				
0	1	Type 2 clocking method		1	0	Idle state clock = 1
		Idle state clock = 1				First edge clock is data capture strobe
		First edge clock is data capture strobe				
1	0	Type 3 clocking method		0	1	Idle state clock = 0
		Idle state clock = 0				First edge clock is data drive strobe
		First edge clock is data drive strobe				
1	1	Type 4 clocking method		0	0	Idle state clock = 0
		Idle state clock = 0				First edge clock is data capture strobe
		First edge clock is data capture strobe				

In both NEC Electronics CSI and SPI communication, when the first edge SCK is used as the data capture strobe, Chip Select (SS_B) is used as a "start of transmission" signal. In this case, the **Chip Select** pin should be driven inactive and then active again between data transmissions, as shown in Figure 6.

When the first edge SCK is used as the data drive strobe, the first edge SCK is the start of transmission signal. In this case, the **Chip Select** pin can remain in the active state between data transmissions.

Figure 6.



2.4 Examples of SPI Peripherals

The following examples of SPI peripherals show two temperature sensors, with similar but slightly different SPI hardware. This application note will show how both of these devices can be interfaced to an NEC Electronics MCU without additional hardware.

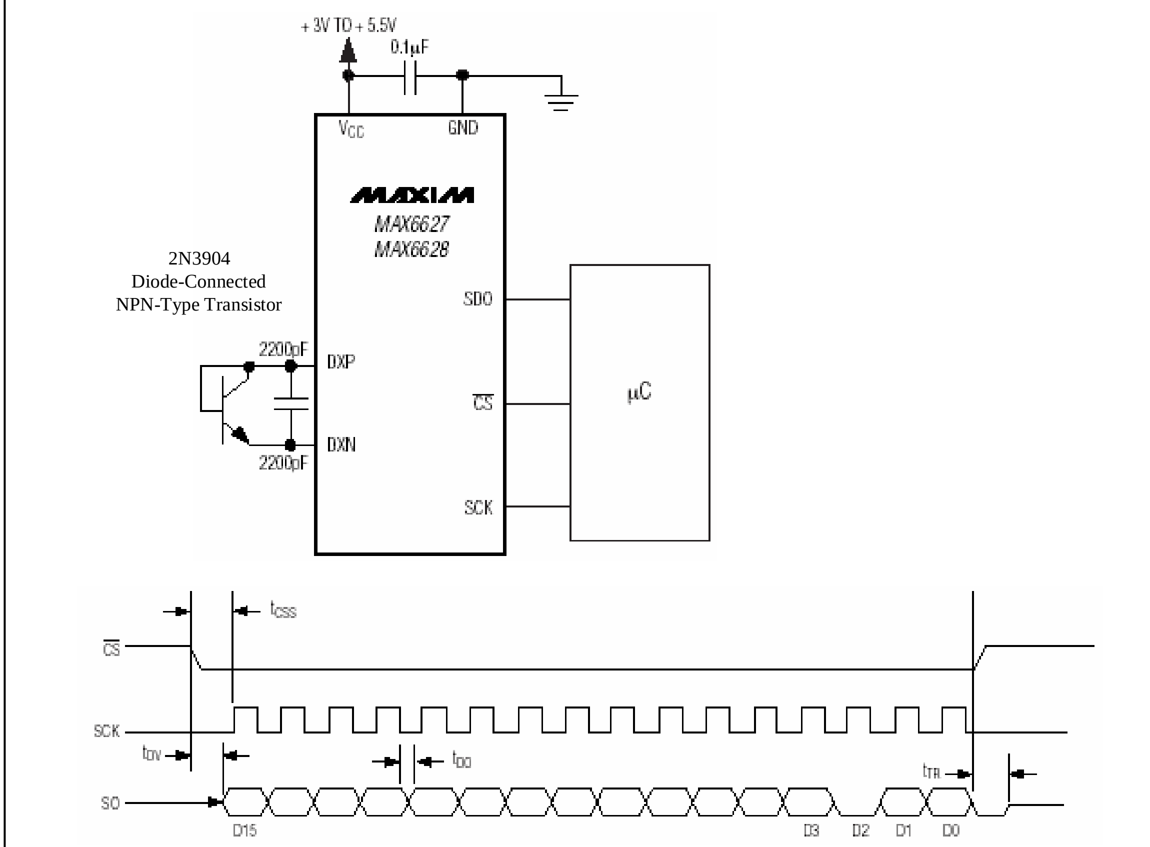
2.4.1 Maxim MAX6627

The Maxim MAX6627 is a remote temperature sensor with a built-in SPI-compatible serial interface that connects to a remote diode-connected transistor for sensing temperature of the transistor.

The MAX6627 sensor is a read-only slave device that has SCK (serial clock) and SDO (serial data output) pins, but no serial data input pin. The SCK input is driven by the master unit; the SDO output would be connected to the SI (serial input) of the master.

The CS (chip select) pin controls sensing and communication. When CS is high, the MAX6627 performs a temperature conversion once every second and stores the result internally. When CS is low, the MAX6627 stops conversion, and is selected for communication. This means CS must be driven by the master.

Figure 7. Maxim MAX6627 Remote Temperature Sensor



The interface to the master unit expects SCK to be low when idle; for an SPI controller, this would require CPOL=0. It uses the first edge of SCK as the data capture strobe and the trailing edge as the data drive strobe; the first data drive strobe is the transition of CS from high to low. For an SPI controller, this would require CPHA=0. This is equivalent to an NEC Electronics Type 4 CSI interface.

SPI clocking method	CPOL = 0	CPHA = 0	
NEC Electronics CSI clocking type	CKPn = 1	DAPn = 1	Type 4 interface

When the chip select line is activated, the first data bit is driven on SDO by the MAX6627, is clocked into the MCU by the rising edge of SCK, and then the next data bit is driven on the falling edge of SCK. Sixteen clocks drive sixteen bits of data, from D15 (MSB) to D0 (LSB). The data contains the temperature reading as a signed value, with a sign bit (D15), twelve bits of temperature data (D14 to D3), a zero bit (D2), and two bits not driven (D1 and D0).

The twelve bits of temperature data is in degrees centigrade, with the upper eight bits (D14 to D7) indicating degrees, and the lower four bits (D6 to D3) indicating sixteenths of a degree. If the lower three bits are masked to zero, the 16-bit signed value can be taken as (temperature in ºC) × 128.

Table 3. Examples of Binary, Hexadecimal, and Degree Representations of Temperature Data

Binary Temperature Data	Hexadecimal Temperature Data	Temperature (ºC)
0100 1000 1000 0000	4880H	145
0011 1100 0000 0000	3C00H	120
0011 0010 0000 0000	3200H	100
0001 1011 1000 0000	1B80H	55
0000 1010 0000 0000	0A00H	20
0000 0000 1000 0000	0080H	1
0000 0000 0000 1000	0008H	0.0625 (1/16)
0000 0000 0000 0000	0000H	0
1111 1111 1111 1000	FFF8H	–0.0625 (–1/16)
1111 1111 1000 0000	FF80H	–1
1111 0110 0000 0000	F600H	–20
1110 0100 1000 0000	E480H	–55

In this format, the maximum positive temperature value would be 7FF8H (0111 1111 1111 1000 binary), equivalent to +255.9375ºC. The maximum negative temperature value would be 8000H (1000 0000 0000 0000 binary), equivalent to –256ºC. The device itself will not operate at these extremes, and data from the remote sensor is only interpreted from –5 to +145ºC.

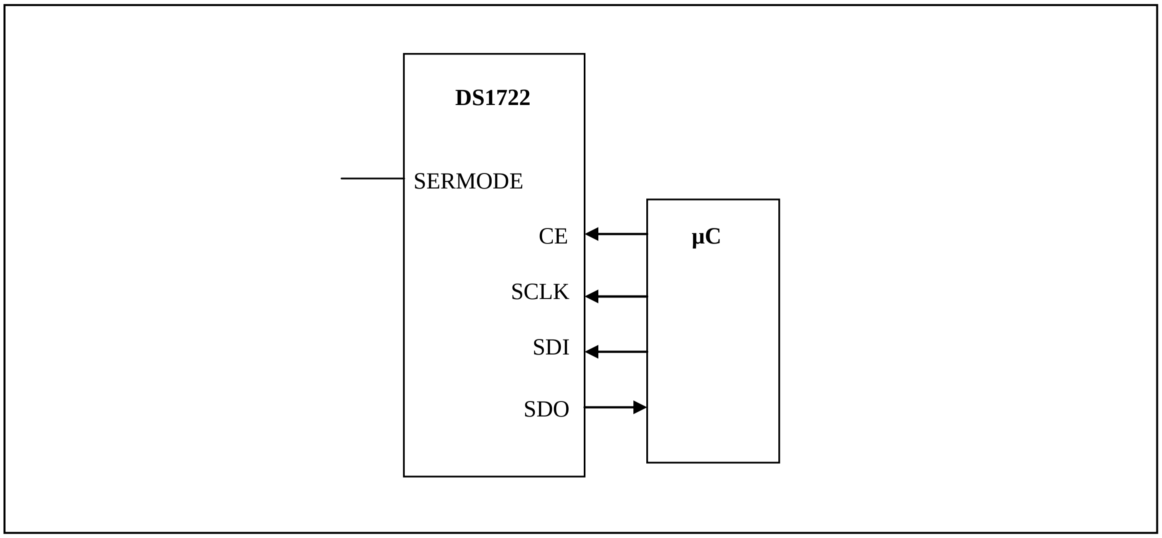
2.4.2 Dallas Semiconductor DS1722

The DS1722 is a temperature sensor device with a built-in SPI-compatible serial interface. This read/write slave device has no remote transistor for temperature sensing; the temperature of the device itself is read. A configuration register can be written, and the temperature high and low bytes and configuration register can be read. The serial clock (SCLK) input is driven by the master unit's SCK signal; the serial data output (SDO) would be connected to the serial input (SI) of the master unit, and the serial data input (SDI) is connected to the serial output (SO) of the master unit.

The DS1722 can do temperature conversions continuously, or one at a time, and then enter a power-down mode (one-shot conversion). The conversion mode is controlled by a bit in the configuration register. The latest temperature conversion is available for reading at any time.

The serial mode (SERMODE) and chip enable (CE) pins control communication. The SERMODE pin selects the communication method; when high, SERMODE selects SPI mode. When CE is high, the DS1722 temperature is enabled for communication and will respond to SCLK by reading SDI and driving SDO; when CE is low, the DS1722 temperature sensor will ignore activity on the SCLK, SDI, and SDO pins.

Figure 8. MCU Connections to DS1722 Temperature Sensor



The polarity of the serial clock depends on its state when CE is asserted. Assuming SCLK is low when CE goes high, the idle state of SCLK is low, which is equivalent to CPOL=0. If SCLK is high when CE goes high, the idle state of SCLK is high, which is equivalent to CPOL=1.

For compatibility with the MAX6627, we will assume SCLK is low when idle (CPOL=0), and the first edge of SCLK will be a rising edge. The interface to master unit uses the first edge of the serial clock as the data drive strobe (when driving data to the master) and the trailing edge of serial clock as the data capture strobe (when accepting data from the master). For an SPI controller, this would require CPHA=1, which is equivalent to an NEC Electronics CSI type 3 interface.

NEC Electronics CSI clocking type	CKPn = 1	DAPn = 0	Type 3 interface
SPI clocking method	CPOL = 0	CPHA = 1	

After CE is activated, the DS1722 sensor expects the master to transmit an address by sending eight bits of data to SDI; during these eight bits, the SDO output will be in the high-impedance state, and the DS1722 will clock in eight bits of address on the trailing edges of SCLK. Depending on the address, the DS1722 will then drive SDO, ignoring further input on SDI (read operation from DS1722), or will continue to read data on SDI and keep SDO in the high-impedance state (write operation to DS1722).

Figure 9. Read and Write Cycles From the Master to the DS1722 Temperature Sensor

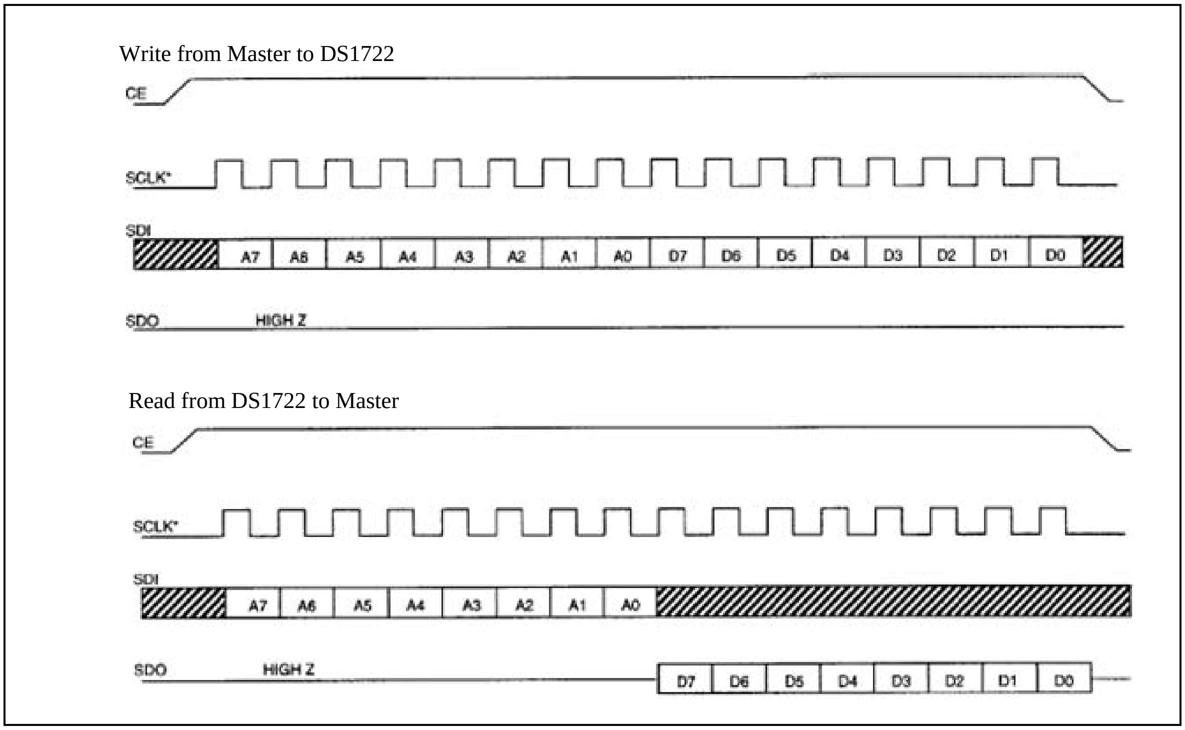


Table 4 lists the addresses accepted by the DS1722 sensor and the action performed on those addresses.

Table 4. Addresses Accepted by the DS1722 Temperature Sensor

SDI first byte (Address)	Second Byte Direction	Second Byte SDI	Second Byte SDO	Data Transferred
00H	Read from DS1722	Ignored	Driven	Configuration register Read
01H	Read from DS1722	Ignored	Driven	Temperature LSB (D15 to D8) read
02H	Read from DS1722	Ignored	Driven	Temperature MSB (D7 to D0) read
80H	Write to DS1722	Accepted	High-Z	Configuration register write

Read transfers from the DS1722 temperature sensor allow multiple registers to be read. The first written byte specifies the address, and the first read byte will be the data from that address. If further bytes are read, the address will be incremented once for each byte read. For example, if address 00H is specified, the first read byte will be the **Configuration** register, the second read byte will be temperature LSB, and third read byte will be temperature MSB.

To read all 16 bits of temperature data, the master would write the address 01H, and then read two bytes (temperature LSB and temperature MSB).

The temperature is a 16-bit signed value, with a sign bit (D15), eleven bits of temperature data (D14 to D4), and four zero bits (D3 to D0). The eleven bits of temperature data is in degrees Centigrade, with the upper seven bits (D14 to D8) indicating degrees, and the lower four bits (D7 to D4) indicating sixteenths of a degree.

The device can be programmed using the configuration register for different accuracies, from 8-bit resolution (to the nearest degree) to 12-bit resolution (to the nearest 1/16th of a degree). Lower accuracies provide faster conversion times between readings.

The 16-bit signed value can be taken as (temperature in degrees Centigrade) × 256. Examples of the binary, hexadecimal, and degree representations of the temperature data are shown in Table 5. Note that the data is different from that of the MAX6627. The reading of fractional degrees assumes 12-bit resolution.

Table 5. Examples of Binary, Hexadecimal, and Degree Representations of Temperature Data

Binary Temperature Data	Hexadecimal Temperature Data	Temperature (ºC)
0111 1000 0000 0000	7800H	120
0110 0100 0000 0000	6400H	100
0011 0111 0000 0000	3700H	55
0001 0100 0000 0000	1400H	20
0000 0001 0000 0000	0100H	1
0000 0000 0001 0000	0010H	0.0625 (1/16)
0000 0000 0000 0000	0000H	0
1111 1111 1111 0000	FFF0H	–0.0625 (–1/16)
1111 1111 0000 0000	FF00H	–1
1110 1100 0000 0000	EC00H	–20
1100 1001 0000 0000	C900H	–55

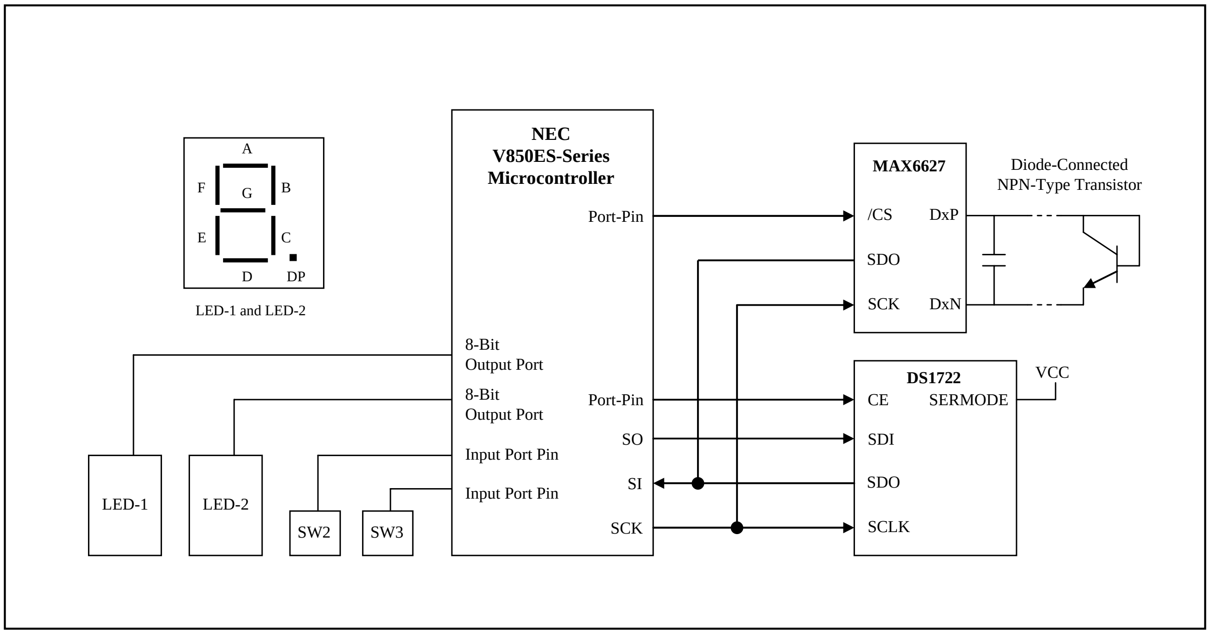
In this format, the maximum positive temperature value would be 7FF0H (0111 1111 1111 0000 binary), equivalent to +127.9375ºC. The maximum negative temperature value would be 8000H (1000 0000 0000 0000 binary), equivalent to –128ºC. The device itself is specified to operate from –55 to +120ºC and would not be able to operate at these extremes.

2.5 Program Description and Specification

The program reads temperature data from two different SPI peripheral temperature sensor devices, a MAX6627 and a DS1722, and displays the current temperature on the two-digit, seven-segment LED. Pressing SW2 reads and displays the temperature from the MAX6627; pressing SW3 reads and displays the temperature from the DS1722.

The V850ES MCU's CSI peripheral is used for communication with the temperature sensor devices, which have built-in SPI peripheral interfaces. For remote sensing of temperature, the MAX6627 temperature sensor uses a diode-connected NPN-type transistor that connects to the temperature-sensing device through a twisted cable and senses the local temperature of the device.

Figure 10. MAX6627 Diode-Connected NPN-Type Transistor



When interfacing with an SPI peripheral, it is necessary to configure the interface from the NEC Electronics V850ES MCU using the clocked serial interface.

1. Determine the SPI peripheral clocking method used.

2. Configure the V850ES MCU's CSI for the equivalent SPI clocking method.

3. Set appropriate registers for the selected CSI unit.

For the MAX6627, the SPI clocking method required is CPOL=0 (SCK idle state low), CPHA=0 (data capture strobe on first clock edge). This requires an NEC Electronics CSI type 4 interface (CKPn=1, DAPn=1).

For the DS1722, the SPI clocking method can have either CPOL=0 (SCK idle state low) if SCK is low when CE is asserted, or CPOL=1 if SCK is high when CE is asserted. In either case, the clock phase required is CPHA=1 (data driven on first clock edge, data capture strobe on clock trailing edge). If we assume CPOL=0, this would require an NEC Electronics CSI type 3 interface.

Since NEC Electronics MCUs often have multiple CSI peripherals, it would be possible to connect the MAX6627 to one set of CSI pins and the DS1722 to another set. However, since the NEC Electronics

CSI unit can be configured easily for one interface type or another, for this example, we connected the two devices to the same pins, and switched from a type 3 interface (when reading the MAX6627) to a type 4 interface (when reading the DS1722).

Two general-purpose I/O port pins are used to drive the MAX6627 Chip Select (/CS) and DS1722 Chip Enable (CE) signals. Note that the /CS signal for the MAX6627 is active low, while the CE signal for the DS1722 is active high.

Specifications

- 5 MHz crystal: 20 MHz system clock
- CSI00: communication with temperature sensors
- CSI00: 8-bit transmit and receive transfers, most significant bit (MSB) first
- CSI00 clock: fxx/4, 5 MHz (max. for MAX6627 and DS1722)
- Temperature data: signed 16-bit read data
- Temperature data from the MAX6627: nearest $1/16^{th}$ of a degree
- DS1722: 10-bit accuracy (to the nearest $1/4^{th}$ of a degree)
- Temperature display: decimal data, scrolling through the LED digits
- Timer TM00: periodic 1 millisecond (ms) interrupt for debouncing switches

2.6 Software Flowcharts

The demonstration program consists of the following major sections:

- Initialization code for the program, called before the main() program starts, including clock and peripheral initialization
- The main program loop, which responds to switches by reading and reporting temperature
- Subroutines for temperature reading and display
- Subroutines for CSI00 peripheral access
- Subroutines for reading switches and displaying data in LED

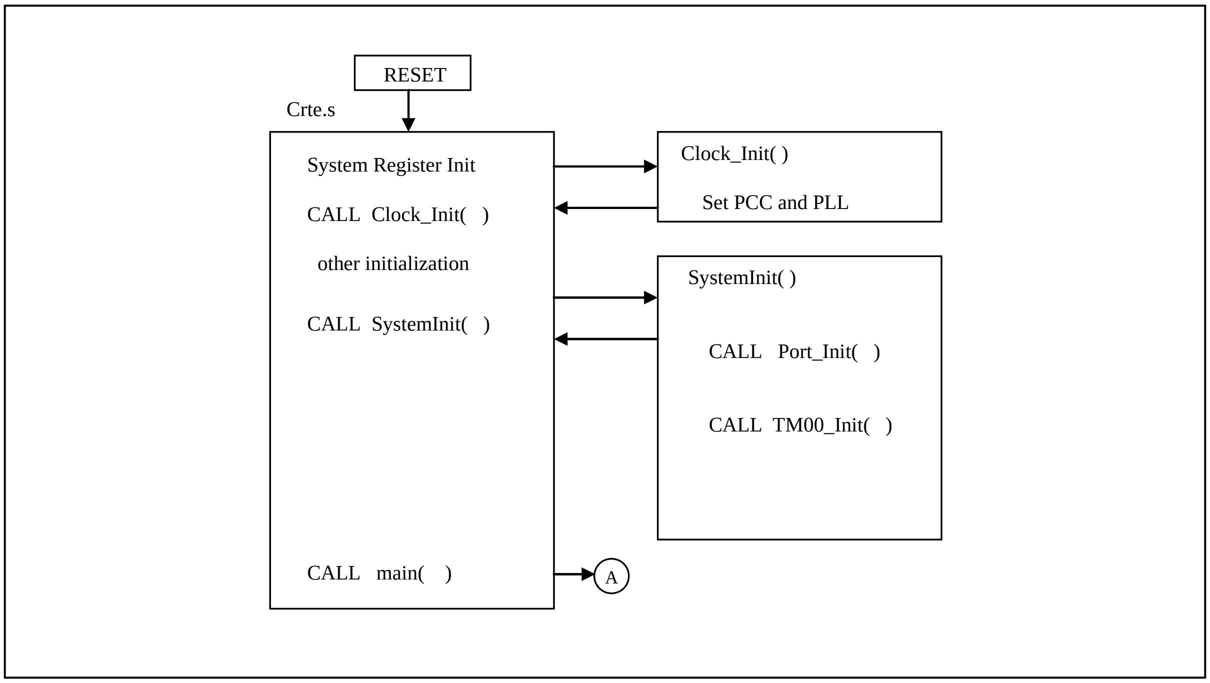
The flowcharts here will describe initialization, the main program, temperature routines, and CSI peripheral access. Flowcharts are not included for timer access, switch reading, or the LED. The software listings include this code.

2.6.1 Program Startup and Initialization

For V850ES programs written in C language, the startup code for the C program is supplied by an assembly language startup file, generally named crte.s. This startup code specifies the reset vector, which determines where the program will begin on a hardware reset and provides initial setup of system registers before calling the main() function.

When Applilet is used to generate a C program for the V850ES MCU, the crte.s startup assembly language file is automatically generated, and includes a call to the Clock_Init() function to set the system clock, and a call to the SystemInit() function which in turn calls initialization routines for some (but not all) peripherals.

Figure 11. crte.s Startup File



After the SystemInit() function finishes, the startup code calls the main() function of the user program. So at the start of the main() function, peripheral initialization has been done for several peripherals. The main() function does not need to call these individual peripheral initialization routines.

Note that SystemInit() does NOT automatically call the CSI00_Init() routine to initialize the CSI00 peripheral.

2.6.2 Main( ): Main Program for NEC Electronics CSI to SPI Serial Communication

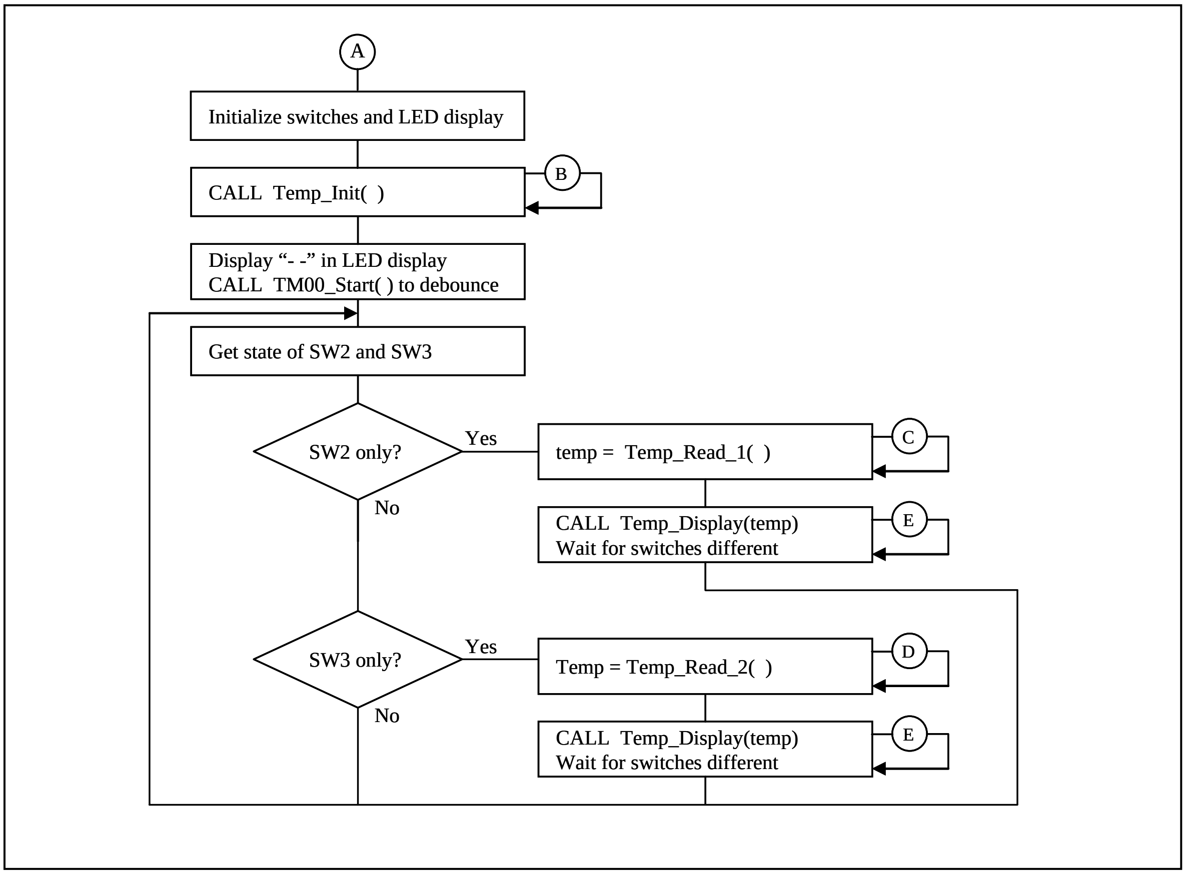
The main( ) program is called from the startup code after peripheral initialization. The program calls routines to initialize input switch handling and LED output.

Main( ) then calls Temp_Init( ) to initialize the temperature sensors and the CSI/SPI interface used to communicate with the sensors. If an error is detected, an error code is displayed and the program enters an endless loop.

To indicate proper initialization, a pair of dashes is shown in the LED. TM00_Start( ) is called to start the TM00 timer for a periodic 1 millisecond interrupt, used for debouncing the input switches.

The main( ) program then enters the main program loop. The program checks the state of the SW2 and SW3 switches for the action to perform.

Figure 12. Main( ): Main Program for NEC Electronics CSI to SPI Serial Communication



If SW2 is pressed, the MAX6627 temperature sensor is read by calling Temp_Read_1( ), and the variable **temp** is set to the value read. The temperature is then displayed in the LED by calling Temp_Display(**temp**). Main() then waits for the switch state to be different.

If SW3 is pressed, the DS1722 temperature sensor is ready by calling Temp_Read_2( ), setting **temp** to the value read. The temperature is then displayed in the LED by calling Temp_Display(**temp**). Main() then waits for the switch state to be different.

After processing the switches, main() returns to the top of the program loop to check switch states again.

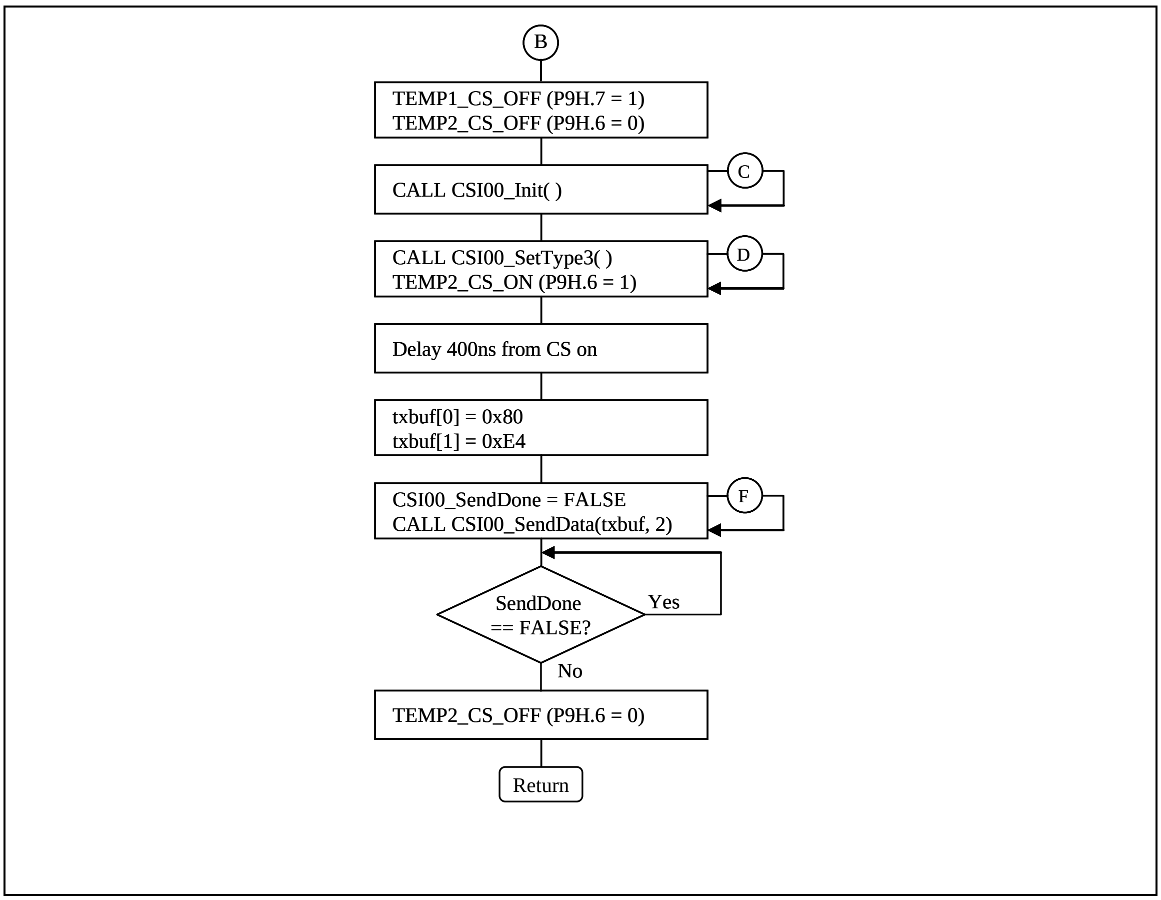
2.6.3 Temp_Init(): Initialize Temperature Sensor Interface

The Temp_Init() routine initializes the temperature sensors to prepare them for reading. Temp_Init() first sets the chip selects for the two temperature sensors to the inactive state, and then calls CSI00_Init() to initialize the clocked serial interface 00 for operation.

For the MAX6627 temperature sensor (TEMP1), temperature conversions are done once per second, and the most recent conversion is available for reading at any time. No further initialization is necessary.

For the DS1722 temperature sensor (TEMP2), the default power-up state is for 8-bit resolution (to the nearest 1ºC), and to enter power-down mode. To program the device for 10-bit resolution and for continuous conversion, the Configuration register must be set.

Figure 13. Temp_Init(): Initialize Temperature Sensor Interface



The Temp_Init() routine initializes the temperature sensors to prepare them for reading. Temp_Init() first sets the chip selects for the two temperature sensors to the inactive state, and then calls CSI00_Init() to initialize the clocked serial interface 00 for operation.

For the MAX6627 temperature sensor (TEMP1), temperature conversions are done once per second, and the most recent conversion is available for reading at any time. No further initialization is necessary.

For the DS1722 temperature sensor (TEMP2), the default power-up state is for 8-bit resolution (to the nearest 1ºC), and to enter power-down mode. In order to program the device for 10-bit resolution and for continuous conversion, the Configuration register must be set.

Temp_Init() calls CSI00_SetType3( ) to set the CSI00 peripheral for the Type-3 interface required for the DS1722, and then sets its chip select active. A delay of 400ns is necessary between chip select active and the first SCK edge, so a delay is done.

In order to write to the Configuration register, two bytes of a transmit data buffer, **txbuf**, are prepared. The first byte, **txbuf[0]**, is set to 80H, which is the address used to write to the DS1722 Configuration register, the second byte, **txbuf[1]**, is set to the value E4H. This value specifies 10-bit resolution and continuous conversion.

The flag **CSI00_SendDone** is set FALSE, the CSI00_SendData(**txbuf**, 2) routine is called to start transmission of two bytes of data contained in the buffer, and then Temp_Init() waits for the flag to be set to TRUE.

After each byte of data is transmitted, the INTCSI00 interrupt will occur, and will be handled by the MD_INTCSI00() interrupt service routine. After the last byte has been transmitted, the **CSI00_SendDone** flag will be set to TRUE, and Temp_Init() will continue, setting the chip select inactive. At this point, initialization of the temperature sensors is complete.

2.6.4 CSI00_Init(): Initialize Clocked Serial I/O 00 Peripheral

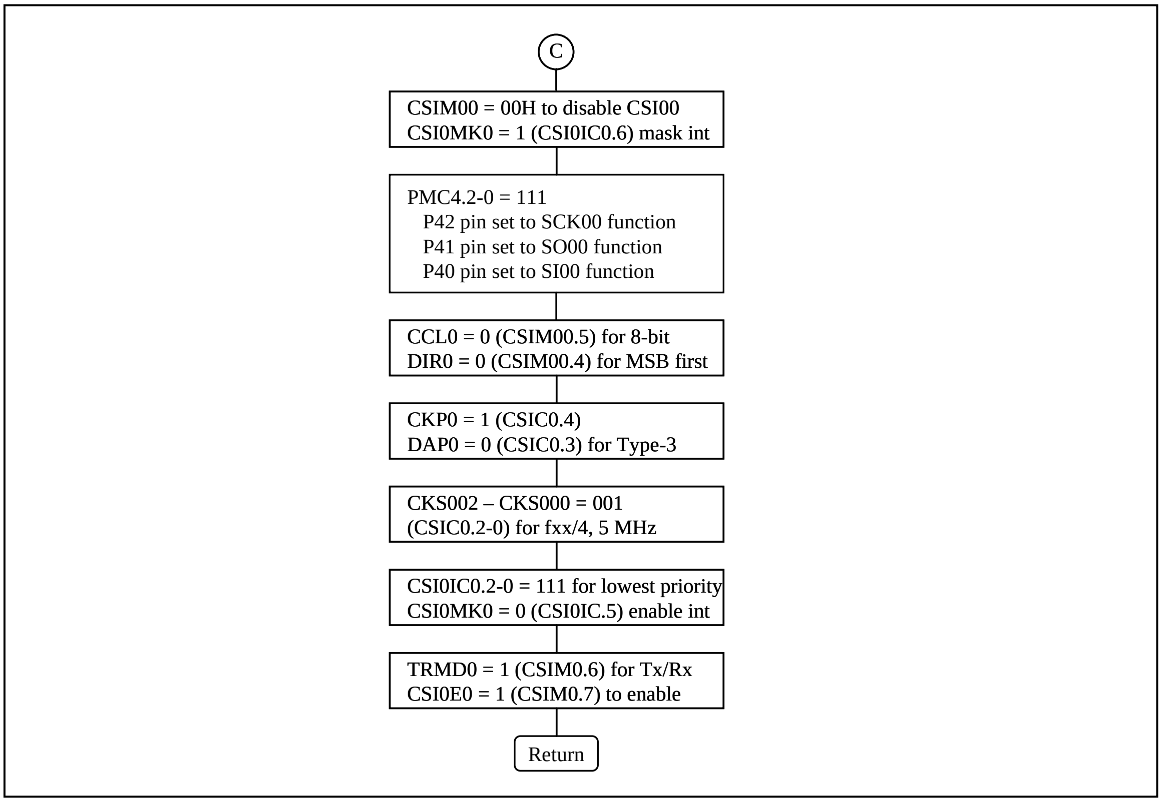
The CSI00_Init() routine sets up the CSI00 peripheral for operation. First the CSIM00 register is set to 00, which disables the CSI00 peripheral, and the INTCSI00 interrupt is disabled by setting the CSK0MK0 mask flag (bit 6 of interrupt control register CSI0IC0).

The port 4 pins used for CSI00 (P42, P41, and P40) are set to their alternate CSI00 functional uses by setting the appropriate bits in the PMC4 **Port Mode Control Register**.

In the CSIM00 control register, the CCL0 bit is cleared to set 8-bit operation, and the DIR0 bit is cleared for MSB-first data transfer.

In the CSIC0 clock control register, the CKP0 (clock polarity) bit is set to one and the DAP0 (data phase) bit is cleared to zero. This sets type 3 operation, equivalent to CPOL=0 and CPHA=1 for SPI peripherals. Note that this will be changed by the CSI00_SetType4() routine, and restored by the CSI00_SetType3() routine, to change modes depending on which SPI peripheral is accessed.

Figure 14. CSI00_Init(): Initialize Clocked Serial I/O 00 Peripheral



The lowest three bits of the CSIC0 clock control register set the clock to be used for the CSI00 peripheral. These are set to 001, to select the clock as fxx/4. Since the system clock is 20 MHz, this setting produces a SCK frequency of 5 MHz, the maximum supported for the two peripherals used.

The interrupt control register CSI0IC0 is set for the lowest priority group, and the INTCSI00 interrupt is enabled by clearing the mask bit CSI0MK0.

In the CSIM0 control register, the TRMD0 bit is set to one to allow transmit/receive operation, and finally the CSI0E0 enable bit is set to enable the CSI00 peripheral to operate.

At this point, the CSI00 peripheral is ready for operation. Writing a byte to the SOTB0L register will begin data transmission and simultaneous reception.

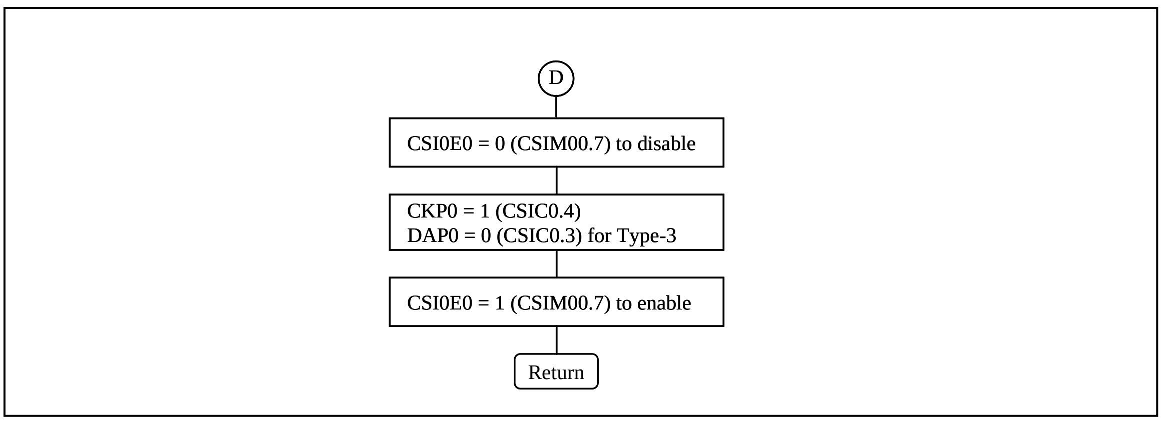
2.6.5 CSI00_SetType3(): Set CSI00 Peripheral for Type 3 Interface

The CSI00_SetType3() routine sets the CSI00 peripheral for type 3 interface, for use with the DS1722 temperature sensor. First the CSI0E0 enable bit in the CSIM00 control register is cleared to disable the CSI00 peripheral. This step is necessary when changing bits that control CSI00 operation.

Then in the CSIC0 clock control registers, the CKP0 (clock polarity) bit is set to 1 (SCK low when idle), and the DAP0 bit (data phase) is cleared to zero (data driven on clock leading edge, data input strobe on clock trailing edge). This sets Type-3 operation, equivalent to CPOL=0 and CPHA=1 for SPI peripherals.

The CSI0E0 enable bit is set to one again, enabling CSI00 operation.

Figure 15. CSI00_SetType3(): Set CSI00 Peripheral for Type 3 Interface



2.6.6 CSI00_SetType4(): Set CSI00 Peripheral for Type 4 Interface

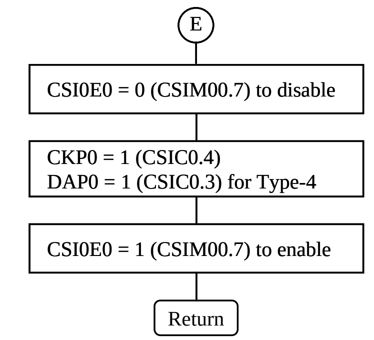
The CSI00_SetType4() routine sets the CSI00 peripheral for type 4 interface, for use with the MAX6627 temperature sensor.

First the CSI0E0 enable bit in the CSIM00 control register is cleared to disable the CSI00 peripheral. This step is necessary when changing bits that control CSI00 operation.

Then in the CSIC0 clock control registers, the CKP0 (clock polarity) bit is set to 1 (SCK low when idle), and the DAP0 bit (data phase) is set to one (data input strobe on clock leading edge, data driven out on clock trailing edge). This sets type 4 operation, equivalent to CPOL=0 and CPHA=0 for SPI peripherals.

The CSI0E0 enable bit is set to one again, enabling CSI00 operation.

Figure 16. CSI00_SetType4(): Set CSI00 Peripheral for Type 4 Interface

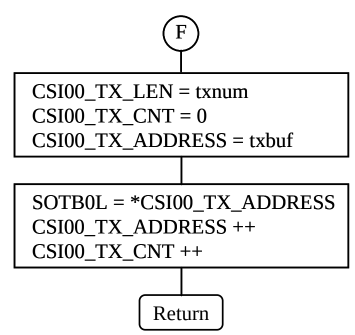


2.6.7 CSI00_SendData(*txbuf, txnum): Start CSI Data Transmission

The CSI00_SendData() routine sets up and starts a transmission operation using CSI00. The **txbuf** parameter is a pointer to an array of bytes to transmit, and the **txnum** parameter is the number of bytes to transmit.

First the routine stores the parameters passed in local copies used in the MD_INTCSI00 interrupt service routine. The **CSI00_TX_LEN** variable is the number of bytes to transmit, and is set to **txnum**; **CSI00_TX_CNT** is the number of bytes sent so far, and is initialized to zero; **CSI00_TX_ADDRESS** is the address of the next byte to send, and is initially set to the **txbuf** pointer passed.

Figure 17. CSI00_SendData(*txbuf, txnum): Start CSI Data Transmission



Then to start the transmit operation, the first byte pointed to is written to the SOTB0L register. The write to this register starts the CSI00 peripheral clocking the SCK00 output, shifting data out on the SO00 output, and clocking data in on the SI00 input. The timing and phase of the data transmission depends on the transfer type set.

The CSI00_SendData() routine sets up and starts a transmission operation using CSI00. The **txbuf** parameter is a pointer to an array of bytes to transmit, and the **txnum** parameter is the number of bytes to transmit.

First the routine stores the parameters passed in local copies used in the MD_INTCSI00 interrupt service routine. The **CSI00_TX_LEN** variable is the number of bytes to transmit, and is set to **txnum**; **CSI00_TX_CNT** is the number of bytes sent so far, and is initialized to zero; **CSI00_TX_ADDRESS** is the address of the next byte to send, and is initially set to the **txbuf** pointer passed.

Then to start the transmit operation, the first byte pointed to is written to the SOTB0L register. The write to this register starts the CSI00 peripheral clocking the SCK00 output, shifting data out on the SO00 output, and clocking data in on the SI00 input. The timing and phase of the data transmission depends on the transfer type set.

After the first byte is written to the transmit register, the pointer is incremented to point to the next byte, and the count is incremented (to one). The routine returns at this point. When the first byte has finished transmission, the INTCSI00 interrupt will occur, and the MD_INTCSI00() interrupt service routine will handle further transmission and reception.

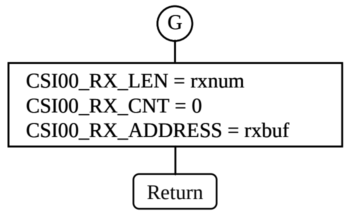
2.6.8 CSI00_ReceiveData(*rxbuf, rxnum): Prepare To Receive Data on CSI00

The CSI00_ReceiveData() routine sets up for data to be received using CSI00. The **rxbuf** parameter is a pointer to an array of bytes to receive the data, and the r**xnum** parameter is the number of bytes to receive.

The routine stores the parameters passed in local copies used in the MD_INTCSI00 interrupt service routine. The **CSI00_RX_LEN** variable is the number of bytes to receive, and is set to **rxnum**; **CSI00_RX_CNT** is the number of bytes received so far, and is initialized to zero; **CSI00_RX_ADDRESS** is the address of the next byte to store received data, and is initially set to the **txbuf** pointer passed.

The routine then returns without any access to the CSI00 peripheral. The values set will be used in the MD_INTCSI00() interrupt service routine when INTCSI00 occurs. To have the interrupt occur, CSI00_SendData() must be called to start a transmission operation.

Figure 18. CSI00_ReceiveData(*rxbuf, rxnum): Prepare To Receive Data on CSI00



2.6.9 MD_INTCSI00() : Interrupt Service Routine for INTCSI00

The MD_INTCSI00() routine is the interrupt service routine for the INTCSI00 interrupt, which occurs after a byte of data has been transmitted by the CSI00 peripheral. The routine handles transmission of the next byte, optional storing of received data, and setting flags to notify the main program of send or receive complete.

The routine first checks if **CSI00_TX_CNT** (count of bytes sent) is equal to **CSI00_TX_LEN** (number of bytes to send). If so, the last byte has been sent, and the callback routine CALL_CSI00_Send() is called. This routine sets the flag **CSI00_SendDone** to TRUE.

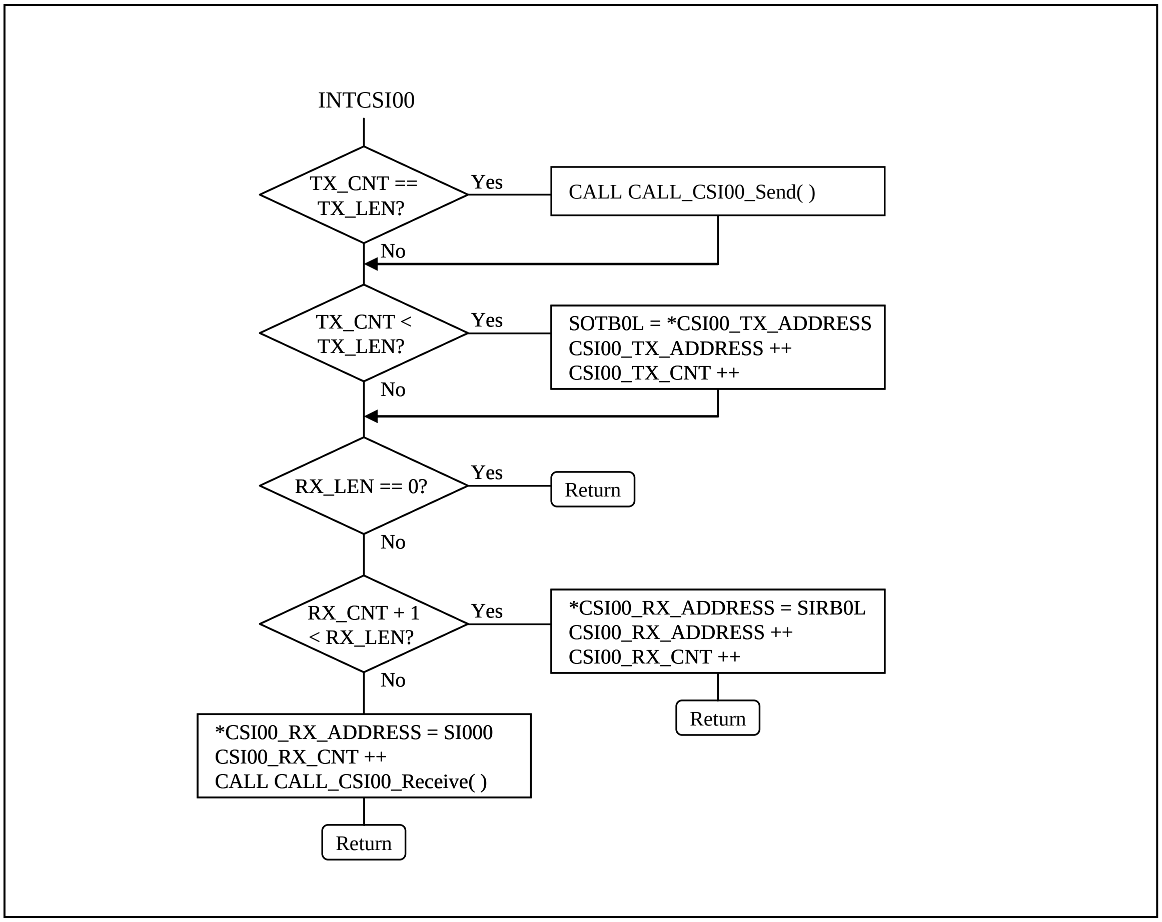
If the send count is less than the number to send, then additional data needs to be sent. The next byte to send, pointed to by **CSI00_TX_ADDRESS**, is written to the SOTB0L register for transmission; **CSI00_TX_ADDRESS** is incremented to point to the next byte, and **CSI00_TX_CNT** is incremented.

When a byte of data is transmitted by being shifted out on the SO output, a separate byte is simultaneously received by shifting data in on the SI input. After a byte has been sent, the received byte is available in the SIRB0L register and in the SI000 serial shift register. Once another byte has begun transmitting, the SI000 serial shift register may no longer contain the previous data, but it is still available in the SIRB0L register.

The MD_INTCSI00() routine checks if data should be received by checking for **CSI00_RX_LEN** being non-zero. If CSI00_ReceiveData() has been called with an non-zero **rxnum** parameter, this will be the case. The routine then checks to see if **CSI00_RX_CNT** plus one is less than **CSI00_RX_LEN**, which will be true for bytes 0 through n-1 of an n-byte receive. If this is the case, data is read from the SIRB0L register, and stored at the location pointed to by **CSI00_RX_ADDRESS**. The address and count are then incremented.

If the count plus one is not less than the length, this is the last byte to receive, and the data is read directly from the SI000 register, stored at the address, and the count is incremented. The callback routine CALL_CSI00_Receive() is called, which sets the **CSI00_ReceiveDone** flag.

Figure 19. MD_INTCSI00() : Interrupt Service Routine for INTCSI00



After processing transmit data and optional received data, the MD_INTCSI00() routine returns to the program at the place where the INTCSI00 interrupt occurred.

2.6.10 Temp_Read_1(): Read Temperature Sensor 1 (MAX6627)

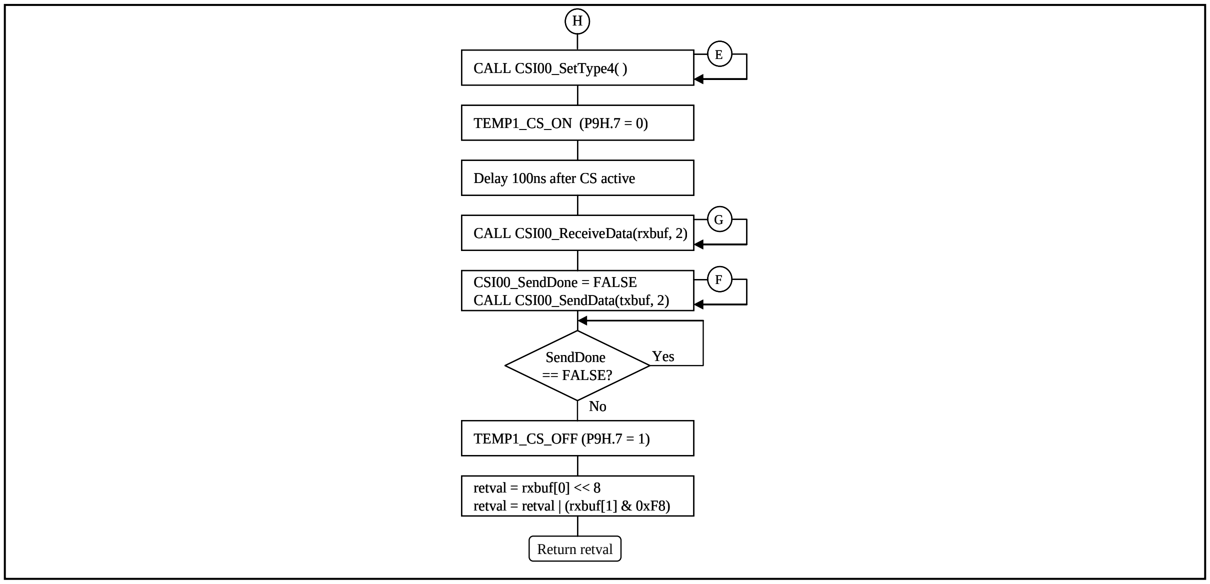
The Temp_Read_1() routine reads the latest temperature reading from the MAX6627 temperature sensor, and returns the value read as a signed 16-bit value, equivalent to (temperature in ºC) × 128.

First the CSI00_SetType4() routine is called, to set the CSI00 transfer type to the proper setting for this device. Then the chip select for the temperature sensor is set on (active low). A short delay is inserted to allow 100ns from chip select to the first serial clock.

The routine then calls CSI00_ReceiveData(rxbuf, 2) to set the location and count of bytes to be read from the CSI00 peripheral. The first parameter, **rxbuf**, is a pointer to an array of byte values to hold the data read; the second parameter, **2**, is the count of bytes to receive.

The routine sets the **CSI00_SendDone** flag to FALSE, and writes two dummy bytes by calling CSI00_SendData(**txbuf**, 2). Because the CSI00 peripheral is in transmit/receive mode, in order to receive data, the transfer must be started by writing a byte of data to the SOTB0L register. This data will be sent out the SO00 output, which is not connected to the MAX6627; the first eight bits of data from the MAX6627 will be clocked in on the SI00 input. Reception of the second eight bits of data is done during the transmission of the second dummy byte.

Figure 20. Temp_Read_1(): Read Temperature Sensor 1 (MAX6627)



The routine then waits for the **CSI00_SendDone** flag to be set to TRUE, which will be done by the MD_INTCSI00() interrupt service routine after the last byte of data is transmitted, which will also have clocked in the last byte to receive.

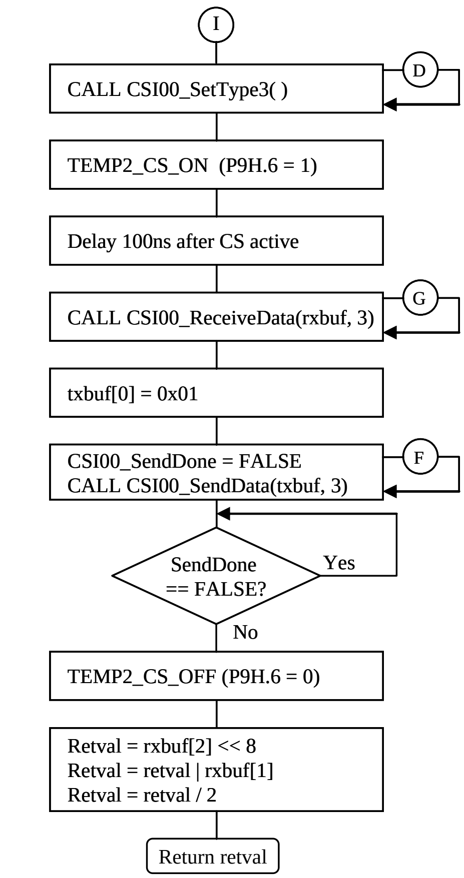
Temp_Read_1() then sets the temperature sensor chip select off, to have the sensor resume temperature readings. It then combines the bytes in **rxbuf[0]** (first eight bits from MAX6627 = Temperature MSB), and **rxbuf[1]** (second eight bits from MAX6627 = temperature LSB) into a signed 16-bit value. It masks the lowest three bits, and returns the 16-bit signed value, which is temperature × 128.

2.6.11 Temp_Read_2(): Read Temperature Sensor 2 (DS1722)

The Temp_Read_1() routine reads the latest temperature reading from the DS1722 temperature sensor, and returns the value read as a signed 16-bit value, equivalent to (temperature in ºC) × 128.

First the CSI00_SetType3() routine is called, to set the CSI00 transfer type to the proper setting for this device. Then the chip select for the temperature sensor is set on (active high). A short delay is inserted to allow 400 ns from chip select to the first serial clock.

Figure 21. Temp_Read_2(): Read Temperature Sensor 2 (DS1722)



The routine then calls CSI00_ReceiveData(rxbuf, 3) to set the location and count of bytes to be read from the CSI00 peripheral. The first parameter, **rxbuf**, is a pointer to an array of byte values to hold the data read; the second parameter, **3**, is the count of bytes to receive.

The routine then sets the first byte of a transmit buffer, **txbuf[0]**, to the address of the temperature low byte, 01H. The routine sets the **CSI00_SendDone** flag to FALSE, and starts the write of the address plus two dummy bytes by calling CSI00_SendData(**txbuf**, 3). The Temp_Read_2() routine then waits for the **CSI00_SendDone** flag to be set.

On the call to CSI00_SendData(txbuf, 3), the transfer is started by writing the first byte of data (01H) to the SOTB0L register. This data will be sent out the SO00 output and received at the SDI input of the DS1722.

After the first byte has been sent, the INTCSI00 interrupt will occur, and the MD_INTCSI00() interrupt service routine will transmit the next byte from **txbuf[1]**, and read the received data into the **rxbuf[0]** location. The first received data will not have been driven by the DS1722, so this first receive byte does not contain temperature data.

While the dummy data in **txbuf[1]** is transmitted, the DS1722 will drive the Temperature low byte out on its SDO pin, and this data will be clocked in on SI00.

After the second byte has been sent, INTCSI00 will occur, and MD_INTCSI00() will transmit **txbuf[2]** and read the received temperature low byte into **rxbuf[1]**. While the dummy data in **txbuf[2]** is transmitted, the DS1722 will have advanced its address to 02H, and will drive the Temperature high byte data out on SDO.

After the third and final byte has been sent, INTCSI00 will occur again, and MD_INTCSI00() will set the **CSI00_SendDone** flag, store the last received byte of data (temperature high byte) into **rxbuf[2]**.

At this point, Temp_Read_2() will see the flag as true, and set the temperature sensor chip select off, to have the sensor resume temperature readings. It then combines the bytes in **rxbuf[1]** (first eight bits from DS1722 = Temperature low byte), and **rxbuf[2]** (second eight bits from DS1722 = Temperature high byte) into a signed 16-bit value. In the 10-bit data resolution selected for the DS1722, this will be (temperature in ºC) × 256, to the nearest 1/4th degree.

To return a temperature value in the same scale as Temp_Read_1(), Temp_Read_2() divides the signed 16-bit data by two, resulting in (temperature in ºC) × 128, and returns this value.

2.6.12 Temp_Display(temp): Show Temperature in LED

The Temp_Display() routine displays the temperature data in the two-digit LED, by scrolling the data through the LED digits. The **temp** parameter is a signed 16-bit value, of temperature × 128. The routine will display digits in the format of (sign)XXX.YY.

Since the details of this routine have nothing to do with the CSI/SPI interface, the flowchart for this routine is not shown. A description of the display format follows. For those interested in the mechanics of the routine, please see the listing in Section 4.

If the temperature is negative, a dash will precede the number for a minus sign, otherwise no sign will be shown.

The data will be shown serially in the two LED digits, scrolling the number through with short delays between shifts. For example the temperature +123.75ºC would be shown as:

“1 2”	hundreds and tens digits
“2 3.”	tens and units digits, with decimal point
“3. 7”	units digit with decimal point, tenths digit
“7 5”	tenths digit, hundredths digit

The temperature –43.275ºC would be shown as

“4 ”	minus sign, tens digits
“4 3.”	tens digit, units digits with decimal point
“3. 2”	units digit with decimal point, tenths digit
“5 7”	tenths digit, hundredths digit (fraction after hundredths truncated)

If the number is such that –100 < temp < +100, no hundreds digit will be shown. If the number is such that –10 < temp < +10, no tens digit will be shown, and a blank or the sign will be displayed. The temperature +5.00ºC would be shown as:

“ 5.”	blank tens digit, units digit with decimal point
“5. 0”	units digit with decimal point, tenths digit
“0 0”	tenths digit, hundredths digit

The temperature of ±5.00ºC would be shown as:

“– 5.”	minus sign, units digit with decimal point
“5. 0”	units digit with decimal point, tenths digit
“0 0”	tenths digit, hundredths digit

2.7 Applilet's Reference Driver

NEC Electronics’ Applilet program generator can automatically generate C or assembly language source code to manage peripherals for the NEC Electronics MCUs. See Section 3 for the version of Applilet used.

Applilet is used to produce the basic initialization code and main function for the program, clock initialization code, initialization and driver code for the CSI00 and timer TM00 peripherals, and initialization for I/O ports used. After Applilet produces the basic code, additional code is added by the user to customize the functioning of the program.

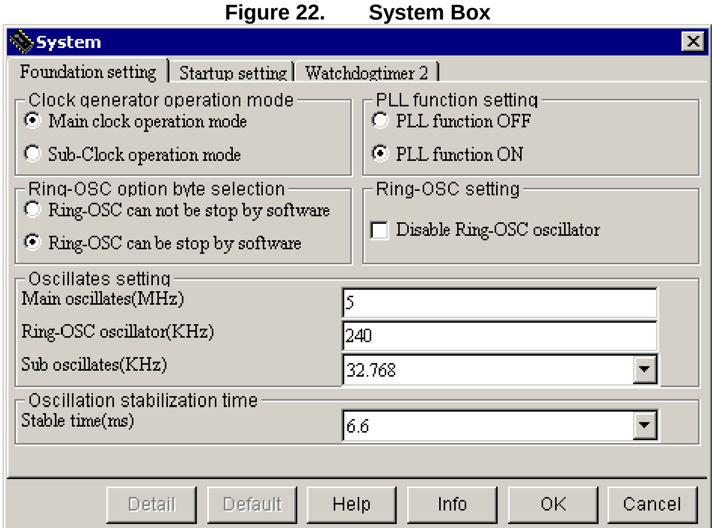
This section describes how Applilet is set up to produce code for these peripherals, and lists the files and routines produced. Additional files not generated by Applilet, such as those written for temperature sensor access, are also listed.

Applilet is started, and a new project file is created and saved as a .prx file. Applilet shows a screen allowing different peripheral blocks to be selected for setup.

2.7.1 Configuring Applilet for Clock Initialization

1. In the **System** box, click the **Foundation setting** tab to select the clocks to be initialized in the Clock_Init() routine.

Figure 22. System Box



2. Select **Main clock operation** to operate on the external crystal

3. Select **PLL function On** to set the clock to use the PLL multiplier.

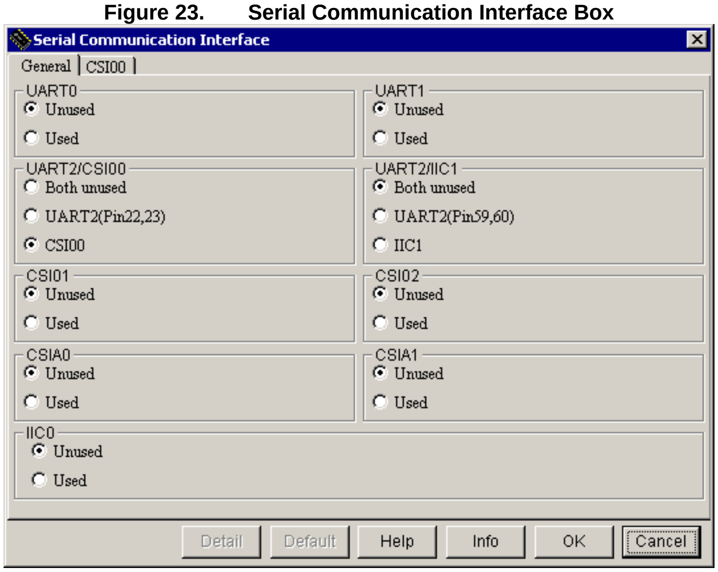
4. In the **Oscillates setting** box, set the **Main oscillator** at 5 MHz. With the PLL on, this results in a system clock of 20 MHz.

5. Select **Ring-OSC option byte selection** box, select **Ring-OSC can be stop by software**. If this option is not selected, the watchdog timer 2 (WDTM2) cannot be stopped and would reset the program periodically if not disabled or cleared within a certain time interval. In order to make the program code clearer, the watchdog timer is not used.

2.7.2 Configuring Applilet for CSI00

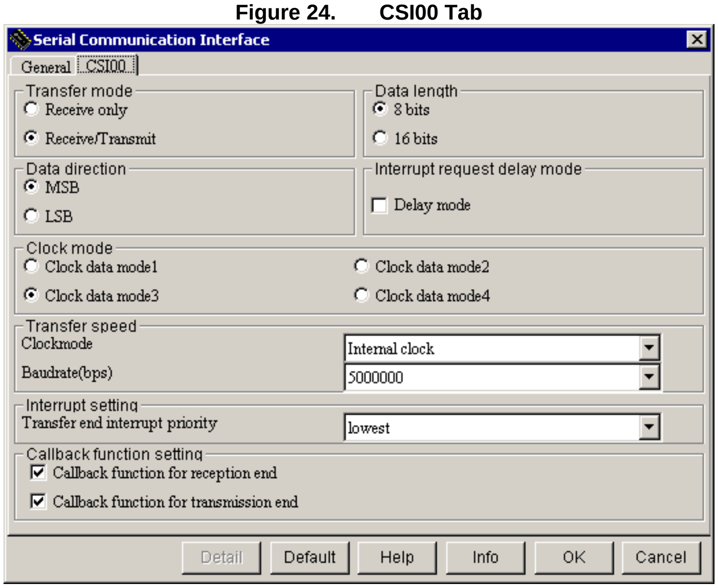
1. In the **Serial Communication Interface** box, select **CSI00** to open the **CSI00** tab.

Figure 23. Serial Communication Interface Box



2. The **CSI00** tab enables you to control the code generated for the CSI00_Init() routine, and for routines used to read and write data.

Figure 24. CSI00 Tab



3. In the **Transfer mode** box, select Receive/Transmit mode, since the DS1722 temperature sensor requires output in order to be configured or read.

4. The MAX6627 temperature sensor provides its temperature data as a 16-bit value; the DS1722 temperature sensor requires an 8-bit output, and provides the temperature as two 8-bit values. Therefore, in the **Data length** box, select **8 bits** to write data and to read the temperature data

in two 8-bit cycles. If the MAX6627 sensor were the only device used, you would need to set the data length to 16 bits.

5. In the **Data direction** box, select **MSB** to match the temperature sensors.

6. The two temperature sensors use different clock types. The MAX6627 uses a type 4 (clock data mode4), and the DS1722 a type 3 (clock data mode3). To manage changing between one type and another, the routines CSI00_SetType3() and CSI_SetType4() were written. For initialization in this example, select **clock data mode3** in the **Clock mode** box.

7. In the **Transfer speed** box, set the baud rate to **5 Mbps** to match the maximum data rate supported by the temperature sensors.

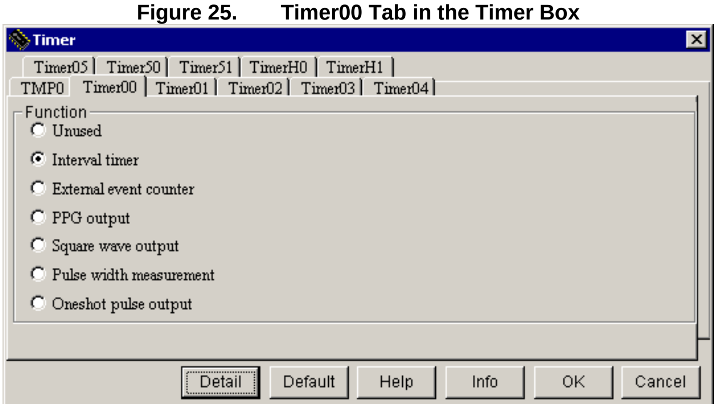
8. In the **Interrupt setting** box, select **lowest**.

9. In the **Callback function setting** box, select **Callback function for reception end** and **Callback function for transmission end** to provide a mechanism to notify the main program when a data reception or transmission operation is complete.

2.7.3 Configuring Applilet for Timer 00 (TM00)

1. On the **Timer00** tab in the **Timer** box, select the **Interval timer** to provide a periodic interrupt, and then click **Detail** to set the details of the Timer 00 interval timer.

Figure 25. Timer00 Tab in the Timer Box



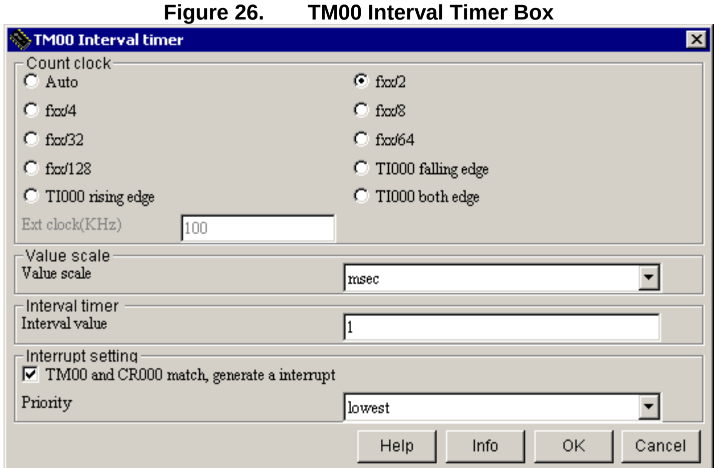
2. In the **Count clock** box, select **fxx/2** to use a 10 MHz clock for the timer.

3. In the **Value scale** box, select **msec** for milliseconds.

4. In the **Interval timer** box, enter **1**.

5. In the **Interrupt setting** box, select **TM00 and CR000 match, generate an interrupt** so that Timer 00 will generate an interrupt every millisecond. This interrupt is used for debouncing the pushbutton switches and to count down a millisecond timer for timing delays.

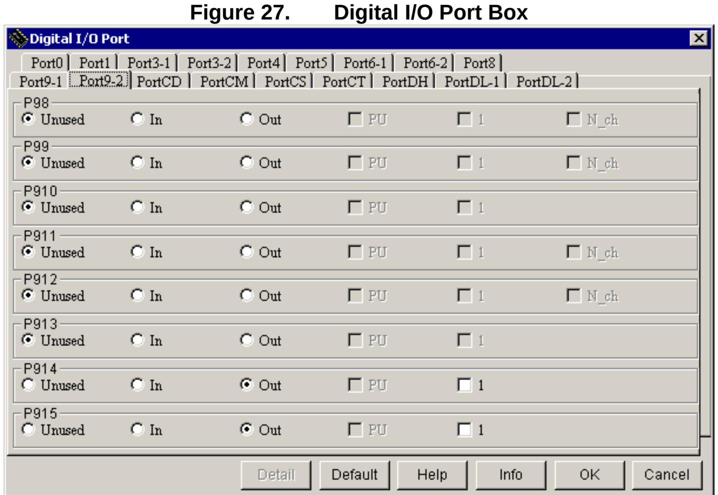
Figure 26. TM00 Interval Timer Box



2.7.4 Configuring Applilet for I/O Ports

1. Open the **Digital I/O Port** box to set the individual port pins for input or output, and to specify settings for the pull-up resistors.

Figure 27. Digital I/O Port Box



2. On the **Port 9-2** tab, set **P914** and **P915** as **outputs**. These pins are used as the chip selects for the temperature sensor. (In the program, when these bits are accessed, the reference is to P9H.6 (P914) and P9H.7. The upper byte of the 16-bit port 9 can be referenced as P9H.)

3. On the **PortDH** tab, set ports **PDH0 through PDH7** as outputs to control LED1.

4. On the **PortDL-2** tab, set ports **PDL8 through PDL15** as outputs to control LED2.

5. On the **Port9-1** tab, set ports **P94** and **P95** as inputs, and also select pull-up resistors for use for these pins. These ports are connected to switches SW2 and SW3, which ground the input when pressed. The pull-up resistor option holds these inputs high when the switch is not pressed.

2.7.5 Generating Code With Applilet

Once the various dialog boxes are set up, select the “Generate code” option. Applilet will show the peripherals and functions to be generated, and allows you to select a directory to store the source code.

When the “Generate” button is pressed, Applilet creates the code in several C-language source files (extension .c), C header files (extension .h), and assembly language source and header files (extensions .s and .inc), and shows the list of files created in a dialog box.

To support the initial startup code, Applilet generates assembly source file crte.s. For clock initialization, Applilet generates system.inc and system.s. The SystemInit() function is generated in systeminit.c.

To support the CSI00 peripheral, Applilet generates serial.h, serial.c, and serial_user.c. See details on these files below.

To support the Timer00 peripheral, Applilet generates timer.h, timer.c and timer_user.c.

To support I/O port initialization, Applilet generates port.h and port.c.

Several other files are generated, including a main.c file with a blank main function. Applilet also generates a link directive file, 850.dir, to control the linking process.

2.7.6 Applilet-Generated Files

For the demonstration program, Applilet generated several source files. The files and their functions are shown below.

Table 6. Applilet-Generated Source File

File	Function
Macrodriver.h	General header file for Applilet-generated programs
Crte.s	Reset vector, program startup code
System.inc	Assembly-language header for system.s
System.s	Assembly source for Clock_Init() routine
System_user.s	Empty file (would contain code for System interrupt if used)
Systeminit.c	SystemInit() routine for peripheral initialization
Main.c	The main program routine
Inttab.s	Interrupt vectors with RETI for unused interrupts
Port.h	Header file defining initial port states
Port.c	Port_Init() routine
Serial.h	Header file for serial.c
Serial.c	CSI00 functions generated by Applilet
Serial_user.c	Callback functions for UART1 and CSI00, for user code

File	Function
Timer.h	Header file for timer.c
Timer.c	Timer 00 functions
Timer_user.c	User code for INTTM000 interrupt
850.dir	Link directive file

2.7.7 Applilet-Generated Files for CSI00 Operation

The code generated for CSI00 support are in the files serial.h, serial.c, and serial_user.c. These contain the following items.

2.7.7.1 Serial.h

The header file serial.h contains definitions for the CSI00 functions. The header file macrodriver.h, used for all Applilet generated code, also defines some data types and values, such as the MD_STATUS values returned by some functions.

2.7.7.2 Serial.c

The source file serial.c contains the following functions generated by Applilet:

1. **void CSI00_Init(void)**: Initializes the CSI00 peripheral as specified in the Applilet CSI00 dialog;

2. **MD_STATUS CSI00_SendData(UCHAR* txbuf, UCHAR txnum)**: Sets up a transmit operation of txnum characters from the txbuf buffer; will also start the transmission operation by sending the first byte to the SOTB0L register

3. **MD_STATUS CSI00_ReceiveData(UCHAR* rxbuf, UCHAR rxnum)**: Sets up a receive operation, requesting rxnum characters be received to the rxbuf buffer. This routine does not start a CSI00 transfer operation; reception is started by calling CSI00_SendData() to send bytes.

4. **__interrupt void MD_INTCSI00(void):** The interrupt service routine for the CSI00 interrupt INTCSI00. For transmit operations, sends the next data and increments the count; when done, calls the CALL_CSI00_Send() callback routine. For receive operations, stores the received data to the receive buffer and increments the count.

2.7.7.3 Serial_user.c

The source file serial_user.c contains stub functions for user code. These functions are empty on code generation, to allow the user to add application-specific code.

1. **void CALL_CSI00_Send(void):** This routine is called when a transmission is complete. Code was added here to set a flag, CSI11_SendDone, to indicate to the main program that transmit is complete.

2. **void CALL_CSI00_Receive(void):** This routine is called when a reception is complete. Code was added here to set a flag, CSI11_ReceiveDone, to indicate to the main program that receive is complete.

The following routines were written and added in serial_user.c; they were not generated by Applilet.

1. **void CSI00_SetType3(void)**: This routine disables the CSI00 peripheral temporarily, sets the peripheral for Type-3 operation, and enables the peripheral again.

2. **void CSI00_SetType4(void)**: This routine disables the CSI00 peripheral temporarily, sets the peripheral for Type-4 operation, and enables the peripheral again.

2.7.8 Files for Temperature Sensor Routines

The following files were written for temperature sensor handling.

2.7.8.1 Temper.h

The header file temper.h contains declarations for the functions for temperature sensor access.

2.7.8.2 Temper.c

The source file temper.c contains the following functions for temperature sensor access:

1. **MD_STATUS Temp_Init(void)**: Initialize temperature sensors and CSI00 serial channel for access.

2. **short Temp_Read_1(void)**: Read temperature value from temperature sensor 1 (MAX6627), returns temperature as a signed 16-bit value, of temperature in degrees Centigrade × 128.

3. **short Temp_Read_2(void)**: Read temperature value from temperature sensor 2 (DS1722), returns temperature as a signed 16-bit value, of temperature in degrees Centigrade × 128.

4. **void Temp_Display(short temp)**; Displays the temperature in the two-digit LED by scrolling the signed decimal value of the temperature through the digits.

2.7.9 Other Demonstration Program Files Not Generated by Applilet

The demonstration program also includes the following files, not generated by Applilet.

Table 7. Program Files Not Generated By Applilet

File	Function
Sw_vkj1.h	Header file for push-button switch input
Sw_vkj1.c	Code to read and debounce pushbutton switches
Led_vkj1.h	Header file for seven-segment LED patterns and functions
Led_vkj1.c	Code to display data in seven-segment LEDs

2.8 Demonstration Platform

A demonstration platform was chosen from the NEC development tools available at the time when this document was prepared. In some cases users may be able to duplicate the same hardware by using standard off-the-shelf components along with the NEC MCU of interest.

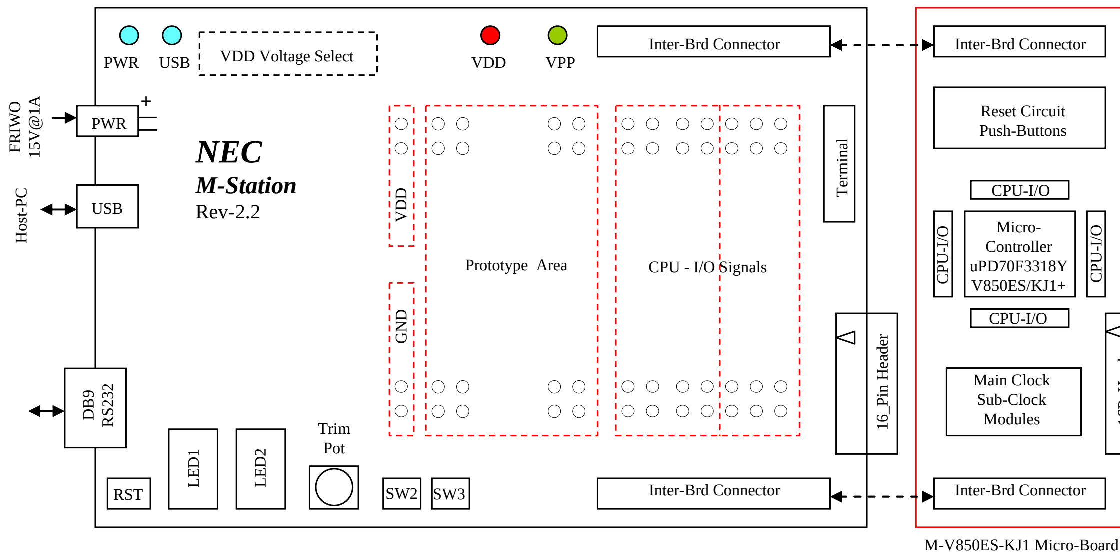
2.8.1 Resources

To demonstrate the program, the following resources have been used:

- M-V850ES-KJ1 micro-board, with µPD70F3318Y (V850ES/KJ1+) 32-bit MCU mounted
- M-Station II Evaluation System, using M-Station II resources:
  - 7-Segment LEDs LED1 and LED2
  - Pushbutton switches SW2 and SW3
- Temperature Sensor MAX6627, mounted on M-Station II
- Remote diode-connected transistor as temperature probe
- Temperature sensor DS1722, mounted on the M-Station II

For details on the hardware listed above, please refer to the appropriate user's manual, available from NEC Electronics America upon request. For details on the MAX6627 and DS1722 devices, please refer to the manufacturers' data sheets.

Figure 28. Block Diagram of Program Resources



2.8.2 Demonstration of Program

Assuming the hardware has been configured correctly, the µPD70F3318Y MCU has been programmed with the demonstration program code, demonstration is as follows:

5. On Reset of the CPU, observe two dashes on the LED. Press SW2 to read and display the temperature as sensed by the probe attached to the MAX6627 device. The temperature will be displayed serially through the LED. For example, the temperature +35ºC would be displayed as:

   – 3 5. blank tens digit, units digit with decimal point

   – 5. 0 units digit with decimal point, tenths digit

   – 0 0 tenths digit, hundredths digit

6. Press SW3 to read and display the temperature as sensed by DS1722 device. The temperature will be displayed serially through the LED. For example, the temperature +27.25ºC would be displayed as:

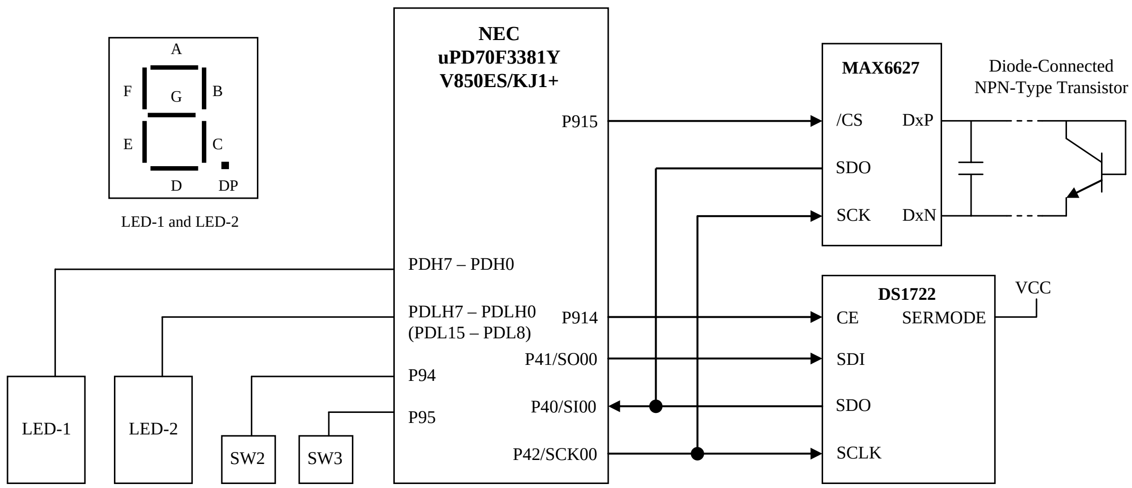
   – 2 7. blank tens digit, units digit with decimal point

   – 7. 2 units digit with decimal point, tenths digit

   – 2 5 tenths digit, hundredths digit

7. Change the temperature at the devices, and check the temperature as reported by pressing SW2 and SW3.

Figure 29. Hardware Block Diagram



The µPD70F3318Y port pins for LED 1 and LED 2 are listed in Table 8. The PDL port is a 16-bit I/O port. The upper eight bits of this port are used for LED-2. For 8-bit access, the upper part of PDL can be referred to as PDLH; the I/O port bit PDLH.6 is the same as PDL.14 and uses the pin PDL14.

Table 8. Port Pins for LED1 and LED2

Segment	LED1	LED2
A	PDH0	PDL8 (PDLH0)
B	PDH1	PDL9 (PDLH1)
C	PDH2	PDL10 (PDLH2)
D	PDH3	PDL11 (PDLH3)
E	PDH4	PDL12 (PDLH4)
F	PDH5	PDL13 (PDLH5)
G	PDH6	PDL14 (PDLH6)
Decimal point	PDH7	PDL15 (PDLH7)

Table 9. MCU Port Pins Used for Other I/O

I/O	LED-1
SW2 input	P94
SW3 input	P95
MAX6627 chip select	P915 (P9H.7)
DS1722 chip select	P914 (P9H.6)
Serial Data In	P40/SI00
Serial Data Out	P41/SO00
Serial Clock	P42/SCK00

2.9 Software Modules

The table below shows which files were generated by Applilet, and which of those needed modification to create the demonstration program.

The listings for these files are located in section 5.

Table 10. Software Modules for the Demonstration Program

File	Purpose	Generated By Applilet	Modified By User
Main.c	Main program	Yes	Yes
Macrodriver.h	General definitions used by Applilet	Yes	No
Crte.s	Reset vector, program startup code	Yes	No
Inttab.s	Interrupt vectors for non-used interrupts (RETI)	Yes	No
System.inc	Clock-related definitions	Yes	No
System.s	Clock_Init() function	Yes	Yes[Note 1]
System_user.c	File for System interrupt	Yes	No
Systeminit.c	SystemInit() and hdwinit() functions	Yes	No
Port.h	Header file defining initial port states	Yes	No
Port.c	Port_Init() routine	Yes	No
Serial.h	CSI00-related definitions	Yes	Yes[Note 2]
Serial.c	CSI00-related functions	Yes	Yes[Note 2]
Serial_user.c	User code in CSI00 callback routines	Yes	Yes[Note 2]
Timer.h	Timer-related definitions	Yes	No
Timer.c	Timer-related functions	Yes	No
Timer_user.c	User code for timer interrupt service	Yes	Yes[Note 3]
850.dir	Link directive file	Yes	No
Temper.h	Temperature sensor definitions	No	--
Temper.c	Temperature sensor functions	No	--
Sw_vkj1.h	Pushbutton switch definitions	No	--
Sw_vkj1.c	Pushbutton switch functions	No	--
Led_vkj1.h	LED definitions	No	--
Led_vkj1.c	LED functions	No	--

Notes

1. System.s was modified to correct an error in the Clock_Init() routine which resulted in excessive time spent waiting for the PLL to stabilize.

2. Serial.h was modified to add the declarations of global variables related to CSI00, defined in Serial_user.c. Serial.c was modified to correct an error in the MD_INTCSI00() interrupt service routine.. Serial_user.c had global variables added, code inserted in callback functions to set these variables, and the routines CSI00_SetType3() and CSI00_SetType4() added.

3. Timer_user.c was modified to add the code to handle the periodic INTTM000 interrupt in the MD_INTTM000() routine, which polls the pushbutton switch state to debounce the switches, and to add routines for millisecond timing.

3. DEVELOPMENT TOOLS

The following software and hardware tools were used in the development of this application note.

Table 11. Software Tools

Tool	Version	Comments
Applilet	E1.46c	Source code generation tool for NEC devices
V850ESKX1H.mcu	V1.33	Applilet MCU configuration for µPD70F3318Y (V850ES/KJ1+)
PM Plus	V6.10	Project manager for program compilation and linking
CA850	V3.00	C compiler, assembler, linker for NEC Electronics V850ES devices
DF3318Y.800	V1.01	Device file for uPD70F3318Y (V850ES/KJ1+) device

Table 12. Hardware Tools

Tool	Version	Comments
M-Station 2	V2.1E	Base platform for NEC Electronics micro-board demonstration
M-V850ES-KJ1	V1.0	NEC Electronics micro-board for V850ES/KJ1+; CPU chip is µPD70F3318YGJ

4. SOFTWARE LISTINGS

This application note program is based on specific files and a number of files that are used in other application notes such as "IIC Communication with LCD Module". For this reason, the files are listed in two separate sections.

Since the Applilet code generation tool was used for both programs, there are instances of the same filename, such as serial.h, serial.c, or serial_user.c in each program. At first glance, these files may seem identical, because Applilet may place a large amount of similar code in each version of the file.

However, there are differences in initialization values for registers, or differences in generated code, depending on the options selected in Applilet. The files listed in the sections for each demonstration program may be different from the same-named files in other sections.

4.1 Files for CSI to SPI Demonstration Program

4.1.1 Main.c

```
/*
*****************************************************************************
**
**  This device driver was created by Applilet for the V850ES/KJ1+,
V850ES/KG1+,
**  V850ES/KF1+, V850ES/KE1+ 32-Bit Single-Chip Microcontrollers
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
incurred
**  by customers or third parties arising from the use of this file.
**
**  Filename : main.c
**  Abstract : This file implements main function
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
*****************************************************************************
*/
/*
** ***************************************************************************
** Include files
```

```
** ***************************************************************************
*/
#include "macrodriver.h"
#include "port.h"
#include "timer.h"
#include "serial.h"

/* include for temperature sensors */
#include "temper.h"

/* includes for M-Station I/O */
#include "sw_vkj1.h"    /* switch input */
#include "led_vkj1.h"   /* LED output */

/*
** ***************************************************************************
** MacroDefine
** ***************************************************************************
*/

/*
**---------------------------------------------------------------------------
**  Abstract:
**  Function to check status for error and report problem
**
**  Parameters:  MD_STATUS status
**      if MD_OK, return; if not, display and loop
**  Returns:
**          None (does not return)
**---------------------------------------------------------------------------
*/
void CheckStatusError(MD_STATUS status)
{
      if (status == MD_OK)
            return;
      led_dig_left(0xE);                        /* display "E" for Error */
      led_dig_right(status & 0x0F); /* display low four bits of error code */
      while (1) {
            __nop();    /* endless loop */
            __nop();
            __nop();
      }
}

/*
**---------------------------------------------------------------------------
**
**  Abstract:
**          main function
**
**  Parameters:
**          None
**
**  Returns:
**          None
```

```
**
**---------------------------------------------------------------------------
*/
void  main( void )
{
MD_STATUS status;
unsigned char sw_val;
short temp;             /* 16-bit signed temperature value */

      sw_init();        /* initialize switch variables */
      led_init();       /* initialize LED */

      status = Temp_Init();         /* set up temperature sensors */
      CheckStatusError(status);     /* report error if problem with
initialization */

      led_out_left(LED_PAT_DASH);   /* show dashes before first temperature
read */
      led_out_right(LED_PAT_DASH);

      TM00_Start();     /* start timer for switch debouncing and millisecond
counting */

      while (1) {
            /* check switches for actions to take */
            sw_val = sw_get();      /* get debounced switch state */
            switch (sw_val) {
            case SW_LD_RU:          /* SW2 down, select temp sensor 1 */
                  temp = Temp_Read_1();   /* read temperature sensor 1 */
                  Temp_Display(temp);           /* and display it */
                  while (SW_LD_RU == sw_get())
                        ;           /* wait for switches different */
                  break;
            case SW_LU_RD:          /* SW3 down, select temp sensor 2 */
                  temp = Temp_Read_2();   /* read temperature sensor 2 */
                  Temp_Display(temp);           /* and display it */
                  while (SW_LU_RD == sw_get())
                        ;           /* wait for switches different */
                  break;
            case SW_LD_RD:          /* Both SW2 and SW3 down */
            case SW_LU_RU:          /* Both SW2 and SW3 are up */
            default:
                  break;            /* do nothing if both up or both down */

            }
      } /* end of while (1) loop */

} /* end of main() */
```

4.1.2 Temper.h

```
/*
*****************************************************************************
**
**
**  This file was created for the NEC V850ES SPI/IIC Application Note
```

```
**
**   Copyright(C) NEC Electronics Corporation 2002 - 2006
**   All rights reserved by NEC Electronics Corporation.
**
**   This program should be used on your own responsibility.
**   NEC Electronics Corporation assumes no responsibility for any losses
**   incurred by customers or third parties arising from the use of this file.
**
**   Filename :    temper.h
**   Abstract :    This file implements header for temper.c
**
**   Device:    uPD70F3318Y
**
**   Compiler:  NEC/CA850
**
*****************************************************************************
**
*/
#ifndef     _TEMPER_H_
#define     _TEMPER_H_
/*
*****************************************************************************
**
**   MacroDefine
*****************************************************************************
**
*/

/* Temperature functions */
MD_STATUS Temp_Init(void);                        /* set up temperature sensors
*/
short Temp_Read_1(void);                          /* read temperature sensor 1
*/
short Temp_Read_2(void);                          /* read temperature sensor 2
*/
void Temp_Display(short temp);                    /* display temperature value
in LED */

#endif /* _TEMPER_H_ */
```

4.1.3 Temper.c

```
/*
*****************************************************************************
**
**
**   This file was created for the NEC V850ES SPI/IIC Application Note
**
**   Copyright(C) NEC Electronics Corporation 2002 - 2006
**   All rights reserved by NEC Electronics Corporation.
**
**   This program should be used on your own responsibility.
**   NEC Electronics Corporation assumes no responsibility for any losses
**   incurred by customers or third parties arising from the use of this file.
**
```

```
**  Filename :    temper.c
**  Abstract :    This file implements functions for temperature sensors
**
**  Device:    uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
*****************************************************************************
**
*/
/*
*****************************************************************************
**
**  Include files
*****************************************************************************
**
*/
#include "macrodriver.h"
#include "serial.h"            /* for CSI/SPI routines */
#include "timer.h"             /* for timing routines */
#include "led_vkj1.h"   /* for M-Station LED */
#include "temper.h"            /* includes for this file */

/* define TEMP_DEBUG to 1 to use ANI00 input for temperature */
#define TEMP_DEBUG 0

#define TEMP1_CS_OFF    (P9H.7 = 1) /* set P915 (P9H.7) high to deselect
sensor 1 */
#define TEMP1_CS_ON           (P9H.7 = 0) /* set P915 (P9H.7) low to select
sensor 1 */

#define TEMP2_CS_OFF    (P9H.6 = 0) /* set P914 (P9H.6) low to deselect
sensor 2 */
#define TEMP2_CS_ON           (P9H.6 = 1) /* set P914 (P9H.6) high to select
sensor 2 */

/* global data - buffers for transmit and receive */
UCHAR rxbuf[8];         /* buffer for received data */
UCHAR txbuf[8];         /* buffer for transmit data */

/*
**---------------------------------------------------------------------------
--
**  Abstract:
**    Function to do Temperature Sensor Initialization
**
**  Parameters: None
**  Returns:
**    TRUE if initialize is successful, FALSE if fails
**
**---------------------------------------------------------------------------
--
*/
MD_STATUS Temp_Init(void)
{
```

```
#if (TEMP_DEBUG == 1)
int i;
      /* set up continuous select, 1 buffer mode of operation */
      ADM = 0x00;       /* clear to reset value to stop converter and
generator */
                              /* also sets select mode, normal conversion,
14.4 us conversion time */

      ADMK = 1;         /* mask interrupt */

      ADS = 0x00;       /* no edge detect, software trigger, select ANI0 */

      ADCS2 = 1;        /* set ADCS2 (ADM.0) to enable reference voltage
generator */

      /* delay 14 microseconds; 1 NOP takes 50 nanoseconds at 20 MHz, */
      /* so we need to do 20 NOPs per microsecond; 14 x 20 = 280 = 28 x 10 */
      for (i = 0; i < 28; i++) {
            __asm("nop");
            __asm("nop");
            __asm("nop");
            __asm("nop");
            __asm("nop");
            __asm("nop");
            __asm("nop");
            __asm("nop");
            __asm("nop");
            __asm("nop");
      }

      ADCS = 1;         /* set ADCS (ADM.7) to enable conversion */
#else
      TEMP1_CS_OFF;     /* deselect chips to allow conversion  */
      TEMP2_CS_OFF;
      CSI00_Init();     /* initialize the CSI00 interface */
      /* for Temp Sensor 1 (MAX6627), no further initialization necessary */
      /* for Temp Sensor 2 (DS1722), set configuration */
      CSI00_SetType3();             /* set CSI00 interface for Type 3
transfer */
      TEMP2_CS_ON;                        /* select chip to enable writing */
      /* delay 400ns between CS true and SCK rise */
      /* one NOP takes 50ns at 20MHz, so do eight */
      __asm("nop"); __asm("nop");
      __asm("nop"); __asm("nop");
      __asm("nop"); __asm("nop");
      __asm("nop"); __asm("nop");

      txbuf[0] = 0x80;        /* address set to write configuration register
*/
      txbuf[1] = 0xE0 |       /* top three bits 111 */
                 0x00 | /* bit 4 = 0, 1SHOT is off */
                 0x04 | /* bits 3-1 = 010 for 10-bit accuracy, 0.3 sec
conversion time */
                 0x00;  /* bit 0 = 0, SD shutdown bit is off, do continuous
conversion */
```

```
      CSI00_SendDone = MD_FALSE;    /* set flag false - will be wset true by
INTCSI00 */
      CSI00_SendData(txbuf, 2);     /* transmit address and data for
configuration */

      while (CSI00_SendDone == MD_FALSE)
            ;     /* wait for CSI transfer done */
      TEMP2_CS_OFF;     /* deselect chip to allow conversion to start again
*/

#endif
      return MD_OK;
}

/*
**---------------------------------------------------------------------------
--
**  Abstract:
**    Function to do Temperature Sensor 1 Read
**
**  Parameters: None
**  Returns:
**    short (16-bit signed) temperature value * 128
**
**---------------------------------------------------------------------------
--
*/
short Temp_Read_1(void)
{
#if (TEMP_DEBUG == 1)
unsigned short usi;
unsigned long ul;
short si;

      usi = ADCR;                   /* read the A/D converter: 0000 - FFC0 */

      ul = usi;
      ul = (ul * (205 * 128));      /* scale full range to (0 - 205) * 16 * 8
*/
      ul = ul >> 16;                      /* scale to value plus 4 bits of
16th degrees plus 3 LSB */
      ul = ul & 0xFFFFFFF8;         /* mask 3 LSB to zero */
      si = (short)ul;                     /* now as signed short number 0 -
205 */
      si = si - (55 * 128);         /* now signed short number -55 - 150 */
      return (si);
#else
short retval = 0;
      CSI00_SetType4();             /* set CSI00 interface for Type 4
transfer */
      TEMP1_CS_ON;                        /* select chip to enable reading */
      /* delay 100ns between CS true and SCK rise */
      /* one NOP takes 50ns at 20MHz, so do two */
      __asm("nop");
      __asm("nop");
```

```
      CSI00_ReceiveData(rxbuf, 2);  /* set up to receive two bytes */
      CSI00_SendDone = MD_FALSE;          /* set flag false - will be wset
true by INTCSI00 */
      CSI00_SendData(txbuf, 2);           /* transmit dummy data to start
transfer (number to receive) */

      while (CSI00_SendDone == MD_FALSE)
            ;     /* wait for CSI transfer done */
      TEMP1_CS_OFF;     /* deselect chip to allow conversion to start again
*/

      /* received data is now in rxbuf 0 and 1, with high byte, MSB first, in
rxbuf[0] */
      /* and low byte in rxbuf[1]; clear 3 LSB to zero */
      retval = (rxbuf[0] << 8) | (rxbuf[1] & 0xF8);
      return (retval);
#endif
}

/*
**---------------------------------------------------------------------------
--
**  Abstract:
**    Function to do Temperature Sensor 2 Read
**
**  Parameters: None
**  Returns:
**    short (16-bit signed) temperature value * 128
**
**---------------------------------------------------------------------------
--
*/
short Temp_Read_2(void)
{
#if (TEMP_DEBUG == 1)
unsigned short usi;
unsigned long ul;
short si;

      usi = ADCR;                   /* read the A/D converter: 0000 - FFC0 */

      ul = usi;
      ul = (ul * (205 * 128));      /* scale full range to (0 - 205) * 16 * 8
*/
      ul = ul >> 16;                      /* scale to value plus 4 bits of
16th degrees plus 3 LSB */
      ul = ul & 0xFFFFFFF8;         /* mask 3 LSB to zero */
      si = (short)ul;                     /* now as signed short number 0 -
205 */
      si = si - (55 * 128);         /* now signed short number -55 - 150 */
      return (si);
#else
short retval;
```

```
	CSI00_SetType3();		/* set CSI00 interface for Type 3
transfer */
	TEMP2_CS_ON;				/* select chip to enable
reading */
	/* delay 400ns between CS true and SCK rise */
	/* one NOP takes 50ns at 20MHz, so do eight */
	__asm("nop"); __asm("nop");
	__asm("nop"); __asm("nop");
	__asm("nop"); __asm("nop");
	__asm("nop"); __asm("nop");

	CSI00_ReceiveData(rxbuf, 3);  /* set up to receive three bytes (first
is dummy) */
	txbuf[0] = 0x01;			/* set address to read temperature
low byte */
	CSI00_SendDone = MD_FALSE;		/* set flag false - will be wset
true by INTCSI00 */
	CSI00_SendData(txbuf, 3);		/* transmit address to start
transfer (number to receive) */

	while (CSI00_SendDone == MD_FALSE)
		;	/* wait for CSI transfer done */
	TEMP2_CS_OFF;	/* deselect chip to allow conversion to start again
*/

	/* received data is now in rxbuf 1 and 2, with low byte, MSB first, in
rxbuf[1] */
	/* and high byte in rxbuf[2] */
	retval = (rxbuf[2] << 8) | rxbuf[1];	/* get 16-bit signed
temperature * 256 */
	retval = retval / 2;				/* scale down to
temperature * 128 for compatibility */
	return (retval);
#endif
}

/* routine to delay for 500 msec */
void Temp_Delay_500ms(void)
{
	SetMsecTimer(500);			/* set timer for 500 milliseconds
*/
	while (!CheckMsecTimer())
		;				/* wait for timer done */
}

/*
**-----------------------------------------------------------------------------
--
**  Abstract:
**    Function to do display of temperature value
**
**  Parameters:
**    short temp - 16-bit signed temperature value (temperature * 128)
**  Returns:    None
```

```
**    display temp in degrees in LEDs, turn on decimal point for negative
temperature
**
**---------------------------------------------------------------------------
--
*/
volatile int dig[5];    /* digits xxx.yy */

void Temp_Display(short temp)
{
BOOL negative = MD_FALSE;

      temp = temp / 8;  /* remove 3 LSB, temp is now temperature * 16 */

      if (temp < 0) {
            negative = MD_TRUE;
            temp = -temp;
      }
      /* temp is now a positive number, temperature * 16 */
      dig[0] = temp / 1600;               /* get hundreds digit */
      temp = temp - (dig[0] * 1600);      /* remove hundreds digit */

      dig[1] = temp / 160;                /* get tens digit */
      temp = temp - (dig[1] * 160); /* get remainder */

      dig[2] = temp / 16;                       /* get ones digit */
      temp = temp - (dig[2] * 16);  /* remainder is now number of 16ths */

      temp = temp * 100;                        /* scale up to get .xxyy, now
xx.yy */
      dig[3] = temp / 160;                /* get tenths digit */
      temp = temp - (dig[3] * 160);

      dig[4] = temp / 16;                       /* get hundredths digit */

      /* now display by rolling through display */
      if (negative) {
            /* negative, display sign in left */
            led_out_left(LED_PAT_DASH);         /* display minus sign */
            if (dig[0] != 0) {
                  led_dig_right(dig[0]);
                  Temp_Delay_500ms();
                  led_dig_left(dig[0]);
            }
            if ( (dig[0] != 0) || (dig[1] != 0) ) {
                  led_dig_right(dig[1]);
                  Temp_Delay_500ms();
                  led_dig_left(dig[1]);
            }
      } else {
            /* positive number, start in left digit */
            if (dig[0] != 0) {
                  led_dig_left(dig[0]);
                  led_dig_right(dig[1]);
                  Temp_Delay_500ms();
```

```
            }
            if ( (dig[0] != 0) || (dig[1] != 0) ) {
                  led_dig_left(dig[1]);
            } else {
                  led_out_left(LED_PAT_BLANK);
            }
      }
      led_dig_right(dig[2]);
      led_dp_right(1);
      Temp_Delay_500ms();

      led_dig_left(dig[2]);
      led_dp_left(1);
      led_dig_right(dig[3]);
      Temp_Delay_500ms();

      led_dig_left(dig[3]);
      led_dig_right(dig[4]);
      Temp_Delay_500ms();

      led_dig_left(LED_PAT_BLANK);
      led_dig_right(LED_PAT_BLANK);
}
```

4.1.4 Inttab.s

```
--/*
--
*****************************************************************************
--**
--**  This device driver was created by Applilet for the V850ES/KJ1+,
V850ES/KG1+,
--**  V850ES/KF1+, V850ES/KE1+ 32-Bit Single-Chip Microcontrollers
--**
--**  Copyright(C) NEC Electronics Corporation  2002-2004
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--**
--**  This program should be used on your own responsibility.
--**  NEC Electronics Corporation  assumes no responsibility for any losses
incurred
--**  by customers or third parties arising from the use of this file.
--**
--**  Filename : inttab.s
--**  Abstract : This file implements interrupt vector table
--**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
--**
--
*****************************************************************************
--*/

--INT vector
```

```
---------------------------------------------------------------------
--    variable initiate
---------------------------------------------------------------------

      --.section "RESET", text
      --jr      __start

      .section "NMI", text                --nmi pin input
      reti

      .section "INTWDT1", text            --WDT1 OVF nonmaskable
      reti

      .section "INTWDT2", text            --WDT2 OVF nonmaskable
      reti

      .section "TRAP00", text             --TRAP instruction
      .globl      __trap00
__trap00:
      reti

      .section "TRAP10", text             --TRAP instruction
      .globl      __trap01
__trap01:
      reti

      .section "ILGOP", text              --illegal op code
      .globl      __ilgop
__ilgop:
      reti


      .section "INTWDTM1", text           --WDT1OVF maskable
      reti

      .section "INTP0", text              --INTP0 pin
      reti

      .section "INTP1", text              --INTP1 pin
      reti

      .section "INTP2", text              --INTP2 pin
      reti

      .section "INTP3", text              --INTP3 pin
      reti

      .section "INTP4", text              --INTP4 pin
      reti

      .section "INTP5", text              --INTP5 pin
      reti

      .section "INTP6", text              --INTP6 pin
      reti
```

```
.section "INTTM001", text          --TM00 and CR001 match
reti

.section "INTTM010", text          --TM01 and CR010 match
reti

.section "INTTM011", text          --TM01 and CR011 match
reti

.section "INTTM50", text           --TM50 and CR50 match
reti

.section "INTTM51", text           --TM51 and CR51 match
reti

.section "INTCSI01", text          --CSI01 transfer complete
reti

.section "INTSRE0", text           --UART0 reception error occurence
reti

.section "INTSR0", text            --UART0 reception completion
reti

.section "INTST0", text            --UART0 translation completion
reti

.section "INTSRE1", text           --UART1 reception error occurence
reti

.section "INTSR1", text            --UART1 reception completion
reti

.section "INTST1", text            --UART1 translation completion
reti

.section "INTTMH0", text           --TMH0 and CMP00/CMP01 match
reti

.section "INTTMH1", text           --TMH1 and CMP10/CMP11 match
reti

.section "INTCSIA0", text          --CSIA0 transfer completion
reti

.section "INTIIC0", text           --IIC0 transfer completion
reti

.section "INTAD", text             --AD conversion end
reti

.section "INTKR", text             --key return interrupt
reti
```

```
       .section "INTWTI", text              --watchtimer interval
       reti

       .section "INTWT", text               --watchtimer referemce time
       reti

       .section "INTBRG", text              --watchtimer counter BRG and PRSCM
match
       reti

       .section "INTTM020", text            --TM02 and CR020 match
       reti

       .section "INTTM021", text            --TM02 and CR021 match
       reti

       .section "INTTM030", text            --TM03 and CR030 match
       reti

       .section "INTTM031", text            --TM03 and CR031 match
       reti

       .section "INTCSIA1", text            --CSIA1 transfer completion
       reti

       .section "INTTM040", text            --TM04 and CR040 match
       reti

       .section "INTTM041", text            --TM04 and CR041 match
       reti

       .section "INTTM050", text            --TM05 and CR050 match
       reti

       .section "INTTM051", text            --TM05 and CR051 match
       reti

       .section "INTCSI02", text            --CSI02 transfer completion
       reti

       .section "INTSRE2", text             --UART2 reception error occurence
       reti

       .section "INTSR2", text              --UART2 reception completion
       reti

       .section "INTST2", text              --UART2 translation completion
       reti

       .section "INTIIC1", text             --IIC1 transfer completion
       reti

-- end of file
```

4.1.5 Systeminit.c

```
/*
******************************************************************************
**
**  This device driver was created by Applilet for the V850ES/KJ1+,
V850ES/KG1+,
**  V850ES/KF1+, V850ES/KE1+ 32-Bit Single-Chip Microcontrollers
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
incurred
**  by customers or third parties arising from the use of this file.
**
**  Filename : systeminit.c
**  Abstract : This file implements macro initiate
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
******************************************************************************
*/
/*
** ***************************************************************************
** Include files
** ***************************************************************************
*/
#include "macrodriver.h"
#include "port.h"
#include "timer.h"
#include "serial.h"
/*
** ***************************************************************************
** MacroDefine
** ***************************************************************************
*/
extern unsigned long _S_romp;

/*
**---------------------------------------------------------------------------
**
**  Abstract:
**    Init every Macro
**
**  Parameters:
**    None
**
**  Returns:
```

```
**    None
**
**---------------------------------------------------------------------------
*/
void  SystemInit( void )
{

      _rcopy(&_S_romp, -1);

      __asm("di");                          /* disable interrupt */

      PORT_Init( );                         /* Port initiate */
      TM00_Init( );                         /* TM00 initiate */
      __asm("ei");                          /* enable interrupt */
}
```

4.1.6 Port.h

```
/*
****************************************************************************
**
**  This device driver was created by Applilet for the V850ES/KX1+
**  32-Bit Single-Chip Microcontrollers
**
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**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
incurred
**  by customers or third parties arising from the use of this file.
**
**  Filename : port.h
**  Abstract : This file implements a device driver for the PORT module
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
****************************************************************************
*/

#ifndef     _MDPORT_
#define     _MDPORT_
/*
** *************************************************************************
** MacroDefine
** *************************************************************************
*/
#define     PORT_PMC0   0x0
#define     PORT_PM0    0xff
#define     PORT_PU0    0x0
#define     PORT_P0     0x0
#define     PORT_PU1    0x0
```

```
#define      PORT_PM1     0xff
#define      PORT_P1      0x0
#define      PORT_PMC3    0x0
#define      PORT_PM3     0xffff
#define      PORT_PU3     0x0
#define      PORT_P3      0x0
#define      PORT_PF3     0x0
#define      PORT_PMC4    0x0
#define      PORT_PM4     0xff
#define      PORT_PU4     0x0
#define      PORT_P4      0x0
#define      PORT_PF4     0x0
#define      PORT_PMC5    0x0
#define      PORT_PM5     0xff
#define      PORT_PU5     0x0
#define      PORT_P5      0x0
#define      PORT_PF5     0x0
#define      PORT_PMC6    0x0
#define      PORT_PM6     0xffff
#define      PORT_PU6     0x0
#define      PORT_P6      0x0
#define      PORT_PF6     0x0
#define      PORT_PMC8    0x0
#define      PORT_PM8     0xff
#define      PORT_PU8     0x0
#define      PORT_P8      0x0
#define      PORT_PF8     0x0
#define      PORT_PMC9    0xc000
#define      PORT_PM9     0x3fff
#define      PORT_PU9     0x30
#define      PORT_P9      0x0
#define      PORT_PF9     0x0
#define      PORT_PMCD    0xff
#define      PORT_PCD     0x0
#define      PORT_PMCM    0xff
#define      PORT_PCM     0x0
#define      PORT_PMCCM   0x0
#define      PORT_PMCS    0xff
#define      PORT_PCS     0x0
#define      PORT_PMCCS   0x0
#define      PORT_PMCT    0xff
#define      PORT_PCT     0x0
#define      PORT_PMCCT   0x0
#define      PORT_PMDH    0x0
#define      PORT_PDH     0x0
#define      PORT_PMCDH   0xff
#define      PORT_PMDL    0xff
#define      PORT_PDL     0x0
#define      PORT_PMCDL   0xff00
#define      PORT_PUCD    0x0
#define      PORT_PUCM    0x0
#define      PORT_PUCS    0x0
#define      PORT_PUCT    0x0
#define      PORT_PUDH    0x0
#define      PORT_PUDL    0x0
```

```
void PORT_Init( void );
#endif
```

4.1.7 Port.c

```
/*
***************************************************************************
**
**  This device driver was created by Applilet for the V850ES/KX1+
**  32-Bit Single-Chip Microcontrollers
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
incurred
**  by customers or third parties arising from the use of this file.
**
**  Filename : port.c
**  Abstract : This file implements a device driver for the PORT module
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
***************************************************************************
*/

/*
**=========================================================================
** Include files
**=========================================================================
*/
#include "macrodriver.h"
#include "port.h"

/*
**=========================================================================
** Constants
**=========================================================================
*/
/*
**-------------------------------------------------------------------------
**
**  Abstract:
**           Initialises the I/O module
**
**  Parameters:
**           None
**
**  Returns:
```

```
**          None
**
**-----------------------------------------------------------------------------
*/
void PORT_Init( void )
{
      /* initialize the port registers */
      P0 = PORT_P0;
      P1 = PORT_P1;
      P3 = PORT_P3;
      P4 = PORT_P4;
      P5 = PORT_P5;
      P6 = PORT_P6;
      P8 = PORT_P8;
      P9 = PORT_P9;
      PCD = PORT_PCD;
      PCM = PORT_PCM;
      PCS = PORT_PCS;
      PCT = PORT_PCT;
      PDH = PORT_PDH;
      PDL = PORT_PDL;

      /* initialize the function registers */
      PF3H = PORT_PF3;
      PF4 = PORT_PF4;
      PF5 = PORT_PF5;
      PF6 = PORT_PF6;
      PF8 = PORT_PF8;
      PF9H = PORT_PF9;

       /* initialize the Pull-up resistor option registers */
      PU0 = PORT_PU0;
      PU1 = PORT_PU1;
      PU3 = PORT_PU3;
      PU4 = PORT_PU4;
      PU5 = PORT_PU5;
      PU6 = PORT_PU6;
      PU8 = PORT_PU8;
      PU9 = PORT_PU9;
      PUCD = PORT_PUCD;
      PUCM = PORT_PUCM;
      PUCS = PORT_PUCS;
      PUCT = PORT_PUCT;
      PUDH = PORT_PUDH;
      PUDL = PORT_PUDL;

       /* initialize the mode registers */
      PM0 = PORT_PM0;
      PM1 = PORT_PM1;
      PM3 = PORT_PM3;
      PM4 = PORT_PM4;
      PM5 = PORT_PM5;
      PM6 = PORT_PM6;
      PM8 = PORT_PM8;
      PM9 = PORT_PM9;
```

```
      PMCD = PORT_PMCD;
      PMCM = PORT_PMCM;
      PMCS = PORT_PMCS;
      PMCT = PORT_PMCT;
      PMDH = PORT_PMDH;
      PMDL = PORT_PMDL;

       /*--- initialize the mode control registers ---*/
      PMC0 &= ~PORT_PMC0;
      PMC3 &= ~PORT_PMC3;
      PMC4 &= ~PORT_PMC4;
      PMC5 &= ~PORT_PMC5;
      PMC6 &= ~PORT_PMC6;
      PMC8 &= ~PORT_PMC8;
      PMC9 &= ~PORT_PMC9;
      PMCCM &= ~PORT_PMCCM;
      PMCCS &= ~PORT_PMCCS;
      PMCCT &= ~PORT_PMCCT;
      PMCDH &= ~PORT_PMCDH;
      PMCDL &= ~PORT_PMCDL;
}
```

4.1.8 Serial.h

```
/*
*****************************************************************************
**
**  This device driver was created by Applilet for the V850ES/KX1+
**  32-Bit Single-Chip Microcontrollers
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
incurred
**  by customers or third parties arising from the use of this file.
**
**  Filename : serial.h
**  Abstract : This file implements a device driver for the SERIAL module
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
*****************************************************************************
*/
#ifndef _MDSERIAL_
#define _MDSERIAL_

#define ADR_CSIA0B0           0xfffffe00  /* CSIA0 automatic transfer RAM
address */
#define ADR_CSIA1B0           0xfffffe20  /* CSIA1 automatic transfer RAM
address */
```

```
#define CSIA_AUTORAMSIZE            32    /* CSIA automatic transfer RAM size
*/
#define IIC_RECEIVEBUFSIZE          32

void CSI00_Init( void );
MD_STATUS CSI00_SendData( UCHAR* txbuf, USHORT txnum );
MD_STATUS CSI00_ReceiveData( UCHAR* rxbuf, USHORT rxnum );
void CALL_CSI00_Receive( void );
void CALL_CSI00_Send( void );

enum TransferMode { Send, Receive };

/* flag set by CALL_CSI00_Send() to signal end of transmission */
extern volatile MD_STATUS CSI00_SendDone;

/* flag set by CALL_CSI00_Receive to signal reception done */
extern volatile MD_STATUS CSI00_ReceiveDone;

/* functions to set CSI00 in Type 3 or Type 4 mode */
void CSI00_SetType3(void);
void CSI00_SetType4(void);

#endif      /* _MDSERIAL_ */
```

4.1.9 Serial.c

```
/*
*****************************************************************************
**
**  This device driver was created by Applilet for the V850ES/KX1+
**  32-Bit Single-Chip Microcontrollers
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
incurred
**  by customers or third parties arising from the use of this file.
**
**  Filename : serial.c
**  Abstract : This file implements a device driver for the SERIAL module
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
*****************************************************************************
*/

#include "macrodriver.h"
#include "serial.h"

#pragma interrupt INTCSI00 MD_INTCSI00
```

```
/* CSI00 Transmission */
UCHAR *CSI00_TX_ADDRESS;                    /* csi00 transmit buffer address */
USHORT CSI00_TX_CNT;                        /* csi00 transmit data number */
USHORT CSI00_TX_LEN;                        /* csi00 transmit data length */

/* CSI00 Reception */
UCHAR *CSI00_RX_ADDRESS;
USHORT CSI00_RX_LEN;                        /* csi00 recive buffer size */
USHORT CSI00_RX_CNT;                        /* csi00 recive data count */

#define FIX_APPLILET_CSI00_ISR      1      /* define to fix code */

/*
**-----------------------------------------------------------------------------
-------------------------------
**
**  Abstract:
**    CSI00 interface initialization, the application is responsible for
**    set work mode, transfer speed, data bit length, data direction setting,
**    automatic transfer mode,clock and data phase setting,INTCSI00 parity
**    setting.
**
**  Parameters:
**    None
**
**  Returns:
**    None
**
**-----------------------------------------------------------------------------
-------------------------------
*/
void CSI00_Init( void )
{
      CSIM00 = 0;
      SetIORBit(CSI0IC0, 0x40);           /* Interrupt disabled */

      SetIORBit(PMC4, 0x07);              /* Port setting for
receive/transmit mode*/
      ClrIORBit(CSIM00, 0x20);            /* Set data length is 8 bits */
      ClrIORBit(CSIM00, 0x10);            /* Set data direction is MSB */

      SetIORBit(CSIC0, 0x10);             /* Clock data phase3 */
      SetIORBit(CSIC0, 0x01);             /* fxx/4 */
      SetIORBit(CSI0IC0, Lowest);         /* Set transfer completion
interrupt priority Lowest */

      ClrIORBit(CSI0IC0, 0x40);
      SetIORBit(CSIM00, 0x40);            /* CSI00 work in half-duplex mode
*/
      SetIORBit(CSIM00, 0x80);

      return;
}

/*
```

```
**----------------------------------------------------------------------------
-------------------------------
**
**  Abstract:
**    The Application is responsible for transfer data of CSI00 interface.
**
**  Parameters:
**    txnum:            The number of data to transmit(frame number).
**    txbuf:            Address of transfer buffer.
**
**  Returns:
**    MD_ARGERROR:      illegal argument
**    MD_OK:            transfer success
**
**----------------------------------------------------------------------------
-------------------------------
*/
MD_STATUS CSI00_SendData(UCHAR* txbuf, USHORT txnum)
{
      /* init CSI00 send parameter */
      CSI00_TX_LEN = txnum;               /* send data length */
      CSI00_TX_CNT = 0;             /* send data count */
      CSI00_TX_ADDRESS = txbuf;           /* send buffer pointer */

      SOTB0L = *CSI00_TX_ADDRESS ++ ;
      CSI00_TX_CNT ++ ;

      return MD_OK;
}

/*
**----------------------------------------------------------------------------
-------------------------------
**
**  Abstract:
**    This function receivd data to destination for CSI00 interface and a
**    call back function is provided to high level user.
**
**  Parameters:
**    rxbuf:            Header point of receive buffer.
**    rxnum:            The number of data should be received.
**
**  Returns:
**    MD_ODDBUF:  in 16bit transfer mode, the tx buffer should be even number
**    MD_OK:            transfer success
**
**----------------------------------------------------------------------------
-------------------------------
*/
MD_STATUS CSI00_ReceiveData(UCHAR* rxbuf, USHORT rxnum)
{
      /* init CSI00 receive parameter */
      CSI00_RX_LEN = rxnum;               /* receive data length */
      CSI00_RX_CNT = 0;             /* receive data count */
      CSI00_RX_ADDRESS = rxbuf;
```

```
	return MD_OK;
}

/*
**-----------------------------------------------------------------------------
------------------------------
**
**  Abstract:
**    This function is the high level language interrupt handler
**    for the CSI00 transmission completion interrupt (INTCSI00).
**
**  Parameters:
**    None
**
**  Returns:
**    None
**
**-----------------------------------------------------------------------------
-----------------------------------
*/
__interrupt void MD_INTCSI00( void )
{
	/* Send procedure */
	if( CSI00_TX_LEN == 1 || (CSI00_TX_CNT == CSI00_TX_LEN)){
		/* transmission complete, add user own coding */
		CALL_CSI00_Send();
#if (FIX_APPLILET_CSI00_ISR == 1)
		/* do not return, continue to check receive */
#else
		/* original code returned, which will not receive the last byte
*/
		return;
#endif
	}

	if(CSI00_TX_CNT < CSI00_TX_LEN){
		SOTB0L = *CSI00_TX_ADDRESS ++ ;
		CSI00_TX_CNT ++ ;
	}

	/* Receive procedure */
	if(CSI00_RX_LEN != 0){
		if(CSI00_RX_CNT + 1 < CSI00_RX_LEN){
			*CSI00_RX_ADDRESS ++ = SIRB0L;
			CSI00_RX_CNT ++ ;
		}
		else{ /* last data */
			*CSI00_RX_ADDRESS = SIO00;
			CSI00_RX_CNT ++ ;
			CALL_CSI00_Receive();
		}
	}
}
```

4.1.10 Serial_user.c

```
/*
******************************************************************************
**
**  This device driver was created by Applet for the V850ES/KX1+
**  32-Bit Single-Chip Microcontrollers
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
incurred
**  by customers or third parties arising from the use of this file.
**
**  Filename : serial_user.c
**  Abstract : This file gives callback functions for serial module.
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
******************************************************************************
*/
/*
** ***************************************************************************
** Include files
** ***************************************************************************
*/
#include "macrodriver.h"
#include "serial.h"

/* global data */
/* flag set by CALL_CSI00_Send() to signal end of transmission */
volatile MD_STATUS CSI00_SendDone;

/* flag set by CALL_CSI00_Receive to signal reception done */
volatile MD_STATUS CSI00_ReceiveDone;

/*
**---------------------------------------------------------------------------
**
**  Abstract:
**    This function is a call back function to deal with data process after
**    some frame(s) data transfering of CSI00 interface.
**
**  Parameters:
**    None.
**
**  Returns:
**    None.
**
**---------------------------------------------------------------------------
*/
```

```
void CALL_CSI00_Send( void )
{
      CSI00_SendDone = MD_TRUE;
}

/*
**-----------------------------------------------------------------------------
**
**  Abstract:
**    This function is a call back function to deal with data process after
**    some frame(s) data receiving of CSI00 interface.
**
**  Parameters:
**    None.
**
**  Returns:
**    None.
**
**-----------------------------------------------------------------------------
*/
void CALL_CSI00_Receive( void )
{
      CSI00_ReceiveDone = MD_TRUE;
}

/* function to set CSI00 in Type 3 transfer mode */
void CSI00_SetType3(void)
{
      ClrIORBit(CSIM00, 0x80);      /* disable CSIM00.CSI0E0 when changing
CSIC0 */
      SetIORBit(CSIC0, 0x10);       /* CKP0 (CSIC0.4) = 1, DAP0 (CSIC0.3) = 0
for type 3 */
      ClrIORBit(CSIC0, 0x08);
      SetIORBit(CSIM00, 0x80);      /* enable CSIM00.CSI0E0 */
}

/* function to set CSI00 in Type 4 transfer mode */
void CSI00_SetType4(void)
{
      ClrIORBit(CSIM00, 0x80);      /* disable CSIM00.CSI0E0 when changing
CSIC0 */
      SetIORBit(CSIC0, 0x18);       /* CKP0 (CSIC0.4) = 1, DAP0 (CSIC0.3) = 1
for type 4 */
      SetIORBit(CSIM00, 0x80);      /* enable CSIM00.CSI0E0 */
}
```

4.1.11 Timer_user.c

```
/*
*****************************************************************************
**
**  This device driver was created by Applilet for the V850ES/KJ1+,
V850ES/KG1+,
**  V850ES/KF1+ and V850ES/KE1+ 32-Bit Single-Chip Microcontrollers
```

```
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
**  incurred by customers or third parties arising from the use of this file.
**
**  Filename : timer_user.c
**  Abstract : This file implements a device driver for the timer interrupt
service routine
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
*****************************************************************************
*/
/*
****************************************************************************
**Include files
****************************************************************************
*/
#include "macrodriver.h"
#include "timer.h"

/* add include file for switches */
#include "sw_vkj1.h"

#pragma interrupt INTTM000 MD_INTTM000

/*
****************************************************************************
**MacroDefine
****************************************************************************
*/

/* counter for millisecond timer */
volatile unsigned int milliseconds;

/*
**---------------------------------------------------------------------------
----------
**
**  Abstract:
**    TM00 INTTM000 Interrupt service routine
**
**  Parameters:
**    None
**
**  Returns:
**    None
**
```

```
**---------------------------------------------------------------------------
----------
*/
__interrupt void MD_INTTM000( void )
{
      /* debounce switch status when timer interrupt occurs */
      sw_isr();
      /* count down millisecond timer */
      if (milliseconds > 0)
            milliseconds--;
}

/* set the millisecond timer */
void SetMsecTimer(int time)
{
      milliseconds = time;
}

/* check the millisecond timer */
BOOL CheckMsecTimer(void)
{
      if (milliseconds > 0)
            return MD_FALSE;
      return MD_TRUE;
}
```

4.1.12 850.dir

```
#*
#***************************************************************************
*
#**
#**  This device driver was created by Applilet for the V850ES/KX1+
#**  32-Bit Single-Chip Microcontrollers
#**
#**  Copyright(C) NEC Electronics Corporation 2002-2004
#**  All rights reserved by NEC Electronics Corporation
#**
#**  This program should be used on your own responsibility.
#**  NEC Electronics Corporation assumes no responsibility for any losses
incurred
#**  by customers or third parties arising from the use of this file.
#**
#**  Filename : 850.dir
#**  Abstract : This is the link file for CA850
#**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
#**
#***************************************************************************
*
#*

CONST      : !LOAD ?R V0x400{
      .const        = $PROGBITS ?A .const;
      };
```

```
OPT     : !LOAD ?R V0x7a{
         .opt       = $PROGBITS ?A .opt;
    };

TEXT  : !LOAD ?RX {
      .pro_epi_runtime = $PROGBITS  ?AX;
      .text       = $PROGBITS      ?AX;
};
  DATA      : !LOAD ?RW V0x3ffe000 {

      .data       = $PROGBITS ?AW;
      .sdata            = $PROGBITS ?AWG;
      .sbss       = $NOBITS   ?AWG;
      .bss        = $NOBITS   ?AW;
};

STACK : !LOAD ?RW V0x3ffee00{
      .stack            = $PROGBITS     ?AW     .stack;
};

__tp_TEXT @ %TP_SYMBOL{TEXT};
__gp_DATA @ %GP_SYMBOL{DATA} &__tp_TEXT{DATA};
__ep_DATA @ %EP_SYMBOL;
```

4.1.13 Sw_vkj1.h

```
/* sw_vkj1.h      */
/*    header for M-V850ES-KJ1 CPU board for base board switch reading */
/*  Version:      1.1   05-08-2006  */

#ifndef _SW_VKJ1_H
#define _SW_VKJ1_H

/*********************************************************************/
/* Define definitions                                               */
/*********************************************************************/

/* symbolic definitions for switch inputs */
/* SW2 = left switch = P94 */
/* SW3 = right switch = P95 */
/*
      P95         P94  */
#define     SW_LU_RU    0x30  /* left up, right up     1           1     */
#define SW_LD_RU  0x20  /* left down, right up   1           0     */
#define SW_LU_RD  0x10  /* left up, right down   0           1     */
#define SW_LD_RD  0x00  /* left down, right down 0           0     */

#define     SW_DEF_DEB_COUNT  16    /* default debounce counter   */

/*********************************************************************/
/* Export functions                                                 */
/*********************************************************************/
extern void sw_init(void);                /* init ports and variables for
switch input */
extern unsigned char sw_chk(void);  /* get undebounced switch input */
extern unsigned char sw_get(void);  /* get debounced switch input */
```

```
extern void sw_set_debounce(unsigned char count);     /* set deboune cound */
extern void sw_isr(void);                            /* debounce routine, called by
timer ISR */

#endif      /* _SW_VKJ1_H */
```

4.1.14 Sw_vkj1.c

```
/*    sw_vkj1.c - routines for switch input                          */
/*    for M-V850ES-KJ1 CPU board on M-Station base board    */
/*  Version:      1.1   05-08-2006                                   */

/*          P94 = input for left switch  (SW2)                       */
/*          P95 = input for right switch (SW3)                       */

/*    To connect ports to switches on M-Station 1.1, make the
      following jumper connections between ROW1 and ROW2.
      To connect ports to swtiches on M-Station 2, make sure
      the default SBxx connections are inserted.

      Port  Switch      M-Station 1.1     M-Station 2.2
      ----  ---         -------------     -------------
      P94         SW2         R1.5 - R2.5       SB7
      P95         SW3         R1.6 - R2.6       SB8
*/

/* need pragma declaration to access SFR's in C */
#pragma ioreg

#include "sw_vkj1.h"

/* local variables for switch handling */
static unsigned char sw_last;       /* last debounced switch value */
static unsigned char sw_new;        /* new value being debounced */
static unsigned char sw_deb_value;  /* value of debounce counter */
static unsigned char sw_deb_count;  /* debounce counter */

/*    void sw_init(void) */
/*          set up ports for switch input */
void sw_init(void)
{
#if 0 /* initialization done in Port_Init() by Applilet */
      /* set P94 and P95 to port mode */
      PMC9L &= 0xCF;
      /* set P94 and P95 to inputs */
      PM9L |= 0x30;
      /* set pullups on P94 and P95 */
      PU9L |= 0x30;
#endif
      /* set static variables */
      sw_last = SW_LU_RU;     /* default is right up, left up (no switch
pressed) */
      sw_deb_value = SW_DEF_DEB_COUNT;    /* set default debounce counter
value */
      sw_deb_count = SW_DEF_DEB_COUNT;    /* set counter to max */
```

```
}

/* unsigned char sw_chk(void) */
/*    return input from switches, undebounced */
unsigned char sw_chk(void)
{
      return P9L & 0x30;
}

/* void sw_set_debounce(unsigned char count) */
/*    set the debounce counter value */
void sw_set_debounce(unsigned char count)
{
      sw_deb_value = count;   /* set new debounce counter value */
      sw_deb_count = count;   /* set counter to max */
}

/* unsigned char sw_get(void) */
/*    return debounced switch input */

unsigned char sw_get(void)
{
      return sw_last;
}


/* void sw_isr( void ) */
/* this routine called by periodic timer interrupt to poll and debounce
switches */
/* after a new value has been seen steadily for sw_deb_value times, sw_last
is updated */
void sw_isr( void )
{
unsigned char val;

      val = sw_chk();         /* get current value */
      /* if value is the same as before, no change; reset debounce and return
*/
      if (val == sw_last) {
            sw_deb_count = sw_deb_value;  /* reset debounce counter to max */
            return;
      }

      /* val != sw_last, there is a new input */
      /* if it's not the same as the previous new one, */
      /* set the NEW new one, reset the debounce counter and return */
      if (val != sw_new) {
            sw_new = val;
            sw_deb_count = sw_deb_value;
            return;
      }

      /* val != sw_last, val == sw_new */
      /* count down the debounce counter */
      sw_deb_count--;
```

```
	/* if we have counted down to zero, we have seen the same sw_new */
	/* for debounce count times, it is now the debounced switch value */
	if (sw_deb_count == 0) {
		sw_last = val;
		sw_deb_count = sw_deb_value;
		return;
	}

	/* if still debouncing, just return */
	return;
}
```

4.1.15 Led_vkj1.h

```
/* led_vkj1.h     */
/*    header for M-V850ES-KJ1 CPU board for LED digit display */
/* Version 1.1    05-08-2006
      */

#ifndef _LED_VKJ1_H
#define _LED_VKJ1_H

/*********************************************************************/
/* Define definitions                                                */
/*********************************************************************/

/* LED Patterns for decimal and hex digits, characters */
/*  for individual bits,       ---A---    */
/*   0=on 1=off                     |       |   */
/* bit 0 = segment A          F       B   */
/* bit 1 = segment B          |       |   */
/* bit 2 = segment C           ---G---    */
/* bit 3 = segment D          |       |   */
/* bit 4 = segment E          E       C   */
/* bit 5 = segment F          |       |   */
/* bit 6 = segment G           ---D--- DP */
/* bit 7 = decimal point                    */

#define LED_PAT_0   0xC0
#define LED_PAT_1   0xF9
#define LED_PAT_2   0xA4
#define LED_PAT_3   0xB0
#define LED_PAT_4   0x99
#define LED_PAT_5   0x92
#define LED_PAT_6   0x82
#define LED_PAT_7   0xF8
#define LED_PAT_8   0x80
#define LED_PAT_9   0x98
#define LED_PAT_A   0x88
#define LED_PAT_B   0x83
#define LED_PAT_C   0xC6
#define LED_PAT_D   0xA1
#define LED_PAT_E   0x86
#define LED_PAT_F   0x8E
```

```
#define LED_PAT_BLANK   0xFF
#define LED_PAT_DP            0x7F
#define LED_PAT_DASH    0xBF
#define LED_PAT_ULINE   0xF7
#define LED_PAT_OLINE   0xFE
#define LED_PAT_EQUAL   0xB7

/**********************************************************************/
/* Export functions                                                   */
/**********************************************************************/
extern void led_init(void);                                  /* init ports for
LED output  */
extern void led_out_right(unsigned char val);   /* output value to right LED
      */
extern void led_out_left(unsigned char val);    /* output value to left LED
      */
extern void led_dig_right(unsigned char num);   /* display number in right
LED   */
extern void led_dig_left(unsigned char num);    /* display number in left LED
      */
extern void led_dig(unsigned char num);               /* display number as
hex         */
extern void led_dig_bcd(unsigned char bcdnum);  /* display number as BCD
      */

extern void led_dp_left(unsigned char on);            /* turn on or off left
DP */
extern void led_dp_right(unsigned char on);           /* turn on or off right
DP */

#endif      /* _LED_KJ1_H */
```

4.1.16 Led_vkj1.c

```
/*    led_vkj1.c - routines for LED                        */
/*    for M-V850ES-KJ1 CPU board on M-Station base board    */
/*  Version:      1.1   05-08-2006                                */
/*  Version:    1.2 06-08-2006 added dp routines    */

/*          PDL8-PDL15 = output to right digit (LED2)       */
/*          PDH0-PDH7  = output to left digit  (LED1)       */

/*    To connect ports to LEDs on M-Station 1.1, make the
      following jumper connections between ROW1 and ROW2.
      To connect ports to LEDs on M-Station 2, make sure
      the default SBxx connections are inserted.
      Port  LED         M-Station 1.1     M-Station 2.2
      ----  ---         -------------     -------------
      PDL8        2-A         R1.25 - R2.25     SB27
      PDL9        2-B         R1.26 - R2.26     SB28
      PDL10       2-C         R1.27 - R2.27     SB29
      PDL11       2-D         R1.28 - R2.28     SB30
      PDL12       2-E         R1.29 - R2.29     SB31
      PDL13       2-F         R1.30 - R2.30     SB32
      PDL14       2-G         R1.31 - R2.31     SB33
      PDL15       2-DP  R1.32 - R2.32     SB34
```

```
      PDH0        1-A         R1.17 - R2.17     SB35
      PDH1        1-B         R1.18 - R2.18     SB36
      PDH2        1-C         R1.19 - R2.19     SB37
      PDH3        1-D         R1.20 - R2.20     SB38
      PDH4        1-E         R1.21 - R2.21     SB39
      PDH5        1-F         R1.22 - R2.22     SB40
      PDH6        1-G         R1.23 - R2.23     SB41
      PDH7        1-DP  R1.24 - R2.24     SB42
*/

/* NOTE: on M-Station Base V1.0 prototype, PDH0-PDH7 are    */
/*  located at ROW4.1-8, and need to be wirewrapped to      */
/*  connect to ROW2.17-24 to drive LED1.                    */

/* need pragma declaration to access SFR's in C */
#pragma ioreg

#include "led_vkj1.h"

/* table of bit patterns for seven-segment digits */
static unsigned char dig_tab[] = {
   LED_PAT_0,     /* 0 */
   LED_PAT_1,     /* 1 */
   LED_PAT_2,     /* 2 */
   LED_PAT_3,     /* 3 */
   LED_PAT_4,     /* 4 */
   LED_PAT_5,     /* 5 */
   LED_PAT_6,     /* 6 */
   LED_PAT_7,     /* 7 */
   LED_PAT_8,     /* 8 */
   LED_PAT_9,     /* 9 */
   LED_PAT_A,     /* A */
   LED_PAT_B,     /* B */
   LED_PAT_C,     /* C */
   LED_PAT_D,     /* D */
   LED_PAT_E,     /* E */
   LED_PAT_F      /* F */
};

/*    void led_init(void) */
/*          set up ports for display of LED digits */
void led_init(void)
{
#if 0 /* ports initialized in Port_Init() by Applilet */
      PMCDH = 0x00;           /* set port DH to port mode */
      PMDH = 0x00;            /* set port DH to output */

      PMCDLH = 0x00;          /* set port DL high 8-bits to port mode */
      PMDLH = 0x00;           /* set port DL high 8-bits to output */
#endif
}

/* void led_out_right(unsigned char val) */
/*          output raw data to right LED */
```

```
void led_out_right(unsigned char val)
{
      PDLH = val;
}

/* void led_out_left(unsigned char val) */
/*          output raw data to left LED */
void led_out_left(unsigned char val)
{
      PDH = val;
}

/* void led_dp_left(unsigned char on) */
/* turn on or off left DP */
void led_dp_left(unsigned char on)
{
      if (on == 0)
            PDH = PDH | 0x80; /* set bit 7 high to turn off */
      else
            PDH = PDH & 0x7f; /* set bit 7 low to turn on */
}

/* void led_dp_right(unsigned char on) */
/* turn on or off right DP */
void led_dp_right(unsigned char on)
{
      if (on == 0)
            PDLH = PDLH | 0x80;     /* set bit 7 high to turn off */
      else
            PDLH = PDLH & 0x7f;     /* set bit 7 low to turn on */

}

/* void led_dig_right(unsigned char num) */
/*    display number in right LED */
void led_dig_right(unsigned char num)
{
      if (num > 0x0F) {
            led_out_right(LED_PAT_BLANK);
            return;
      }
      led_out_right(dig_tab[num]);
}

/* void led_dig_left(unsigned char num) */
/*    display number in left LED */
void led_dig_left(unsigned char num)
{
      if (num > 0x0F) {
            led_out_left(LED_PAT_BLANK);
            return;
      }
      led_out_left(dig_tab[num]);
}
```

```
/* void led_dig(unsigned char num) */
/*          display number as hex digits */
/*          num - number to display */
/*                bits 0-3 in right digit */
/*                bits 4-7 in left digit */
void led_dig(unsigned char num)
{
      led_out_right(dig_tab[num & 0x0F]);
      led_out_left(dig_tab[(num >> 4) & 0x0F]);
}

/* void led_dig_bcd(unsigned char bcdnum) */
/*          display two digits of BCD coded bcdnum */
/*          bcdnum - number to display in BCD */
/*                0 - 9     displayed as right decimal digit, left blank */
/*                10 - 99   displayed as two decimal digits */
/*                100 - 255 displayed as blank */
void led_dig_bcd(unsigned char bcdnum)
{
unsigned char tens_dig;

      if (bcdnum > 99) {
            led_out_right(LED_PAT_BLANK); /* display both digits blank */
            led_out_left(LED_PAT_BLANK);
            return;
      }

      if (bcdnum < 10) {
            led_out_right(dig_tab[bcdnum]);     /* just display right LED */
            led_out_left(LED_PAT_BLANK);        /* blank left LED */
            return;
      }

      /* 10 <= bcdnum <= 99 */
      tens_dig = 0;
      do {                    /* calculate ten's place and remainder */
            bcdnum -= 10;     /* by multiple subtractions of 10 */
            tens_dig++;       /* while counting up the tens digit */
      } while (bcdnum >= 10);
      /* now tens_dig has ten's place */
      /* and bcdnum has remainder */
      led_out_right(dig_tab[bcdnum]);
      led_out_left(dig_tab[tens_dig]);
}
```

4.2 Files Common to Serial Communication Demonstration Programs

4.2.1 Macrodriver.h

```
/*
*****************************************************************************
**
**  This device driver was created by Applilet for the V850ES/KJ1+,
V850ES/KG1+,
```

```
**  V850ES/KF1+ and V850ES/KE1+ 32-Bit Single-Chip Microcontrollers
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
**  incurred by customers or third parties arising from the use of this file.
**
**  Filename : macrodriver.h
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
*****************************************************************************
*/

#ifndef     _MDSTATUS_
#define     _MDSTATUS_
#pragma ioreg                /*enable use the register directly in ca850
compiler*/

/* data type defintion */
typedef     unsigned int      UINT;
typedef     unsigned short    USHORT;
typedef     unsigned char     UCHAR;
typedef     unsigned char     BOOL;

#define     MD_ON       1
#define     MD_OFF            0

#define     MD_TRUE     1
#define     MD_FALSE    0

#define MD_STATUS            unsigned short
#define MD_STATUSBASE              0x0
/*status list definition*/
#define MD_OK                      MD_STATUSBASE+0x0 /*register setting OK*/
#define MD_RESET                   MD_STATUSBASE+0x1 /*reset input*/
#define MD_SENDCOMPLETE      MD_STATUSBASE+0x2 /*send data complete*/
#define MD_ADDRESSMATCH      MD_STATUSBASE+0x3 /*IIC slave address match*/
#define MD_OVF                     MD_STATUSBASE+0x4 /*timer count
overflow*/
#define MD_DMA_END                 MD_STATUSBASE+0x5 /*DMA transfer end*/
#define MD_DMA_CONTINUE            MD_STATUSBASE+0x6 /*DMA transfer
continue*/
#define MD_SPT                     MD_STATUSBASE+0x7 /*IIC stop*/
#define MD_NACK                    MD_STATUSBASE+0x8       /*IIC no ACK*/
#define MD_SLAVE_SEND_END          MD_STATUSBASE+0x9       /*IIC slave send
end*/
#define MD_SLAVE_RCV_END           MD_STATUSBASE+0x0 /*IIC slave receive
end*/
```

```
#define MD_MASTER_SEND_END          MD_STATUSBASE+0x11      /*IIC master send
end*/
#define MD_MASTER_RCV_END           MD_STATUSBASE+0x12      /*IIC master
receive end*/


/*error list definition*/
#define MD_ERRORBASE                0x80
#define MD_ERROR                    MD_ERRORBASE+0x0  /*error*/
#define MD_RESOURCEERROR            MD_ERRORBASE+0x1  /*no resource
available*/
#define MD_PARITYERROR              MD_ERRORBASE+0x2  /*UARTn parity error
n=0,1,2*/
#define MD_OVERRUNERROR       MD_ERRORBASE+0x3  /*UARTn overrun error
n=0,1,2*/
#define MD_FRAMEERROR               MD_ERRORBASE+0x4  /*UARTn frame error
n=0,1,2*/
#define MD_ARGERROR                 MD_ERRORBASE+0x5  /*Error agrument input
error*/
#define MD_TIMINGERROR              MD_ERRORBASE+0x6  /*Error timing
operation error*/
#define MD_SETPROHIBITED                  MD_ERRORBASE+0x7  /*setting
prohibited*/
#define MD_ODDBUF             MD_ERRORBASE+0x8  /*in 16bit transfer
mode,buffer size should be even*/
#define MD_DATAEXISTS               MD_ERRORBASE+0x9  /*Data to be
transferred next exists in TXBn register*/

/* macro fucntion definiton */
#define LockInt( ) { __asm("stsr 5,r10"); __asm("push r10"); __asm("di"); }
#define UnlockInt( ) {  __asm("pop r10"); __asm("ldsr r10,5"); }

/*main clock and subclock as clock source*/
enum ClockMode { MainClock, SubClock };
void  Clock_Init( void );
/*clear IO register bit and set IO register bit */
#define ClrIORBit(Reg, ClrBitMap)   Reg &= ~ClrBitMap
#define SetIORBit(Reg, SetBitMap)   Reg |= SetBitMap

enum INTLevel{Highest,Level1,Level2,Level3,Level4,Level5,Level6,Lowest};
enum TrigEdge { None, RisingEdge,FallingEdge, BothEdge };


#define     SYSTEMCLOCK 20000000
#define     SUBCLOCK    32768
#define     MAINCLOCK   5000000

#endif
```

4.2.2 Crte.s

```
#  This device driver was created by Applilet for the V850ES/KX1+
#  32-Bit Single-Chip Microcontrollers
#
#  Copyright(C) NEC Electronics Corporation 2002-2004
```

```
#  All rights reserved by NEC Electronics Corporation
#
#  This program should be used on your own responsibility.
#  NEC Electronics Corporation assumes no responsibility for any losses
incurred
#  by customers or third parties arising from the use of this file.
#
#  Filename : crte.s
#  Abstract : start file for CA850
#  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
#
#                  |        :        |
#                  |        :        |
#         tp -> -+-----------------+ __start     __tp_TEXT
#                  |  start up       |
#                  |---------------- |
#   text section   |                 |
#                  | user program    |
#                  |                 |
#                  |-----------------|
#                  | library         |
#               -+-----------------+
#                  |        :        |
#                  |        :        |
#               -+-----------------+ __argc
#                  |      0          |
#                  |---------------- | __argv
#   data section   |    #.L16        |
#                  |---------------- | .L16
#                  | 0x0,0x0,0x0,0x0 |
#                 -+-----------------+
#                  |                 |
#   sdata section  |                 |
#                  |                 |
#            gp-> -+-----------------+             __ssbss
#                  |                 |
#   sbss section   |                 |
#                  |                 |
#                  +-----------------+ __stack     __esbss     __sbss
#                  | stack area      |
#   bss section    |                 |
#                  |  0x200 bytes    |
#            sp-> -+-----------------+ __stack + STACKSIZE     __ebss
#
#============================================================================
=

#----------------------------------------------------------------------------
-
#     special symbols
#----------------------------------------------------------------------------
-
      .extern __tp_TEXT, 4
      .extern __gp_DATA, 4
      .extern __ep_DATA, 4
```

```
      .extern     __ssbss, 4
      .extern __esbss, 4
      .extern __sbss, 4
      .extern __ebss, 4


#----------------------------------------------------------------------------
-
#      C program main function
#----------------------------------------------------------------------------
-
      .extern     _SystemInit
      .extern     _main
      .extern     _Clock_Init

#----------------------------------------------------------------------------
-
#     for argv
#----------------------------------------------------------------------------
-
      .data
      .size __argc, 4
      .align      4
__argc:
      .word 0
      .size __argv, 4
__argv:
      .word #.L16
.L16:
      .byte 0
      .byte 0
      .byte 0
      .byte 0


#----------------------------------------------------------------------------
-
#     dummy data declaration for creating sbss section
#----------------------------------------------------------------------------
-
      .sbss
      .lcomm      __sbss_dummy, 0, 0


#----------------------------------------------------------------------------
-
#     system stack
#----------------------------------------------------------------------------
-
      .set  STACKSIZE, 0x200
      .bss
      .lcomm      __stack, STACKSIZE, 4
```

```
#---------------------------------------------------------------------------
-
#     RESET handler
#---------------------------------------------------------------------------
-

      .section   "RESET", text
      jr      __start

#---------------------------------------------------------------------------
-
#     start up
#           pointers:  tp - text pointer
#                    gp - global pointer
#                    sp - stack pointer
#                    ep - element pointer
#     exit status is set to r10
#---------------------------------------------------------------------------
-
      .text
      .align      4
      .globl      __start
      .globl  __exit
      .globl      __startend
      .extern  ___PROLOG_TABLE
__start:
      mov   #__tp_TEXT, tp           -- set tp register
      mov   #__gp_DATA, gp           -- set gp register offset
      add   tp, gp                   -- set gp register
      mov   #__stack+STACKSIZE, sp  -- set sp register
      mov   #__ep_DATA, ep           -- set ep register

      .option warning

      mov    1, r11           -- on-chip debug mode
      set1  5, PMC0[r0]
      set1  5, P0[r0]
      st.b   r11, PRCMD[r0]
      st.b   r11, OCDM[r0]

      nop
      nop
      nop
      nop
      nop
      mov   0x1, r11
      st.b r11, VSWC[r0]                 --mainclock over 16.6MHz

      jarl  _Clock_Init, lp          -- call Clock_Init function

      mov   #__ssbss, r13            -- clear sbss section
      mov   #__esbss, r12
      cmp   r12, r13
      jnl   .L11
.L12:
```

```
      st.w  r0, [r13]
      add   4, r13
      cmp   r12, r13
      jl    .L12
.L11:

      mov   #__sbss, r13            -- clear bss section
      mov   #__ebss, r12
      cmp   r12, r13
      jnl   .L14
.L15:
      st.w  r0, [r13]
      add   4, r13
      cmp   r12, r13
      jl    .L15
.L14:

      mov     #___PROLOG_TABLE, r12   -- for prologue/epilogue runtime
      ldsr    r12, 20               -- set CTBP (CALLT base pointer)

      -- IRAM clean up --
      mov 0x3ffd800, r10      -- IRAM start address
      mov 0x3fff000, r11      -- IRAM end address
_clear_loop:                  -- IRAM clean up
      st.w r0, 0x0[r10]
      add 4, r10
      cmp r11,r10
      jnz _clear_loop

      ld.w  $__argc, r6       -- set argc
      movea $__argv, gp, r7         -- set argv
      jarl  _SystemInit, lp         -- call SystemInit function
      jarl  _main,lp          -- call main function
__exit:
      halt                    -- end of program
```

4.2.3 System.inc

```
--/*
--
*****************************************************************************
--**
--**  This device driver was created by Applilet for the V850ES/FE2,
V850ES/FF2,V850ES/FG2
--**  and V850ES/FJ2 32-Bit Single-Chip Microcontrollers
--**
--**  Copyright(C) NEC Electronics Corporation 2002-2004
--**  All rights reserved by NEC Electronics Corporation
--**
--**  This program should be used on your own responsibility.
--**  NEC Electronics Corporation assumes no responsibility for any losses
incurred
--**  by customers or third parties arising from the use of this file.
```

```
--**
--**  Filename : system.inc
--**  Abstract : This file implements a device driver for the SYSTEM module
--**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
--**
--  Device:  uPD70F3318Y
--
--  Compiler:  NEC/CA850
--
--
******************************************************************************
--*/
.set  CG_Mainosc, 0x5
.set  CG_SECURITY0,     0xff
.set  CG_SECURITY1,     0xff
.set  CG_SECURITY2,     0xff
.set  CG_SECURITY3,     0xff
.set  CG_SECURITY4,     0xff
.set  CG_SECURITY5,     0xff
.set  CG_SECURITY6,     0xff
.set  CG_SECURITY7,     0xff
.set  CG_SECURITY8,     0xff
.set  CG_SECURITY9,     0xff
```

4.2.4 System.s

```
--/*
--
******************************************************************************
--
--  This device driver was created by Applilet for the V850ES/KF1+,
V850ES/KG1+,
--  V850ES/KJ1+ 32-Bit Single-Chip Microcontrollers
--
--  Copyright(C) NEC Electronics Corporation 2002-2004
--  All rights reserved by NEC Electronics Corporation
--
--  This program should be used on your own responsibility.
--  NEC Electronics Corporation assumes no responsibility for any losses
incurred
--  by customers or third parties arising from the use of this file.
--
--  Filename : system.s
--  Abstract : This file implements a device driver for the SYSTEM module
--  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
--
--
--  Compiler:  NEC/CA850
--
--
******************************************************************************
--*/
      .include "system.inc"
      .section "OPTION_BYTES", text
```

```
      .byte  0                      --Set to option byte (Ring-OSC cannot be
stopped)
      .byte  0
      .byte  0
      .byte  0
      .byte  0
      .byte  0

      .section "SECURITY_ID", text
      .byte CG_SECURITY0            -- Security ID head
      .byte CG_SECURITY1
      .byte CG_SECURITY2
      .byte CG_SECURITY3
      .byte CG_SECURITY4
      .byte CG_SECURITY5
      .byte CG_SECURITY6
      .byte CG_SECURITY7
      .byte CG_SECURITY8
      .byte CG_SECURITY9            -- Security ID tail

      .text
      .globl      _Clock_Init
      .align      4
--/*
--**-------------------------------------------------------------------------
--
--**
--**  Abstract:
--**  Init the Clock Generator and Watchdog timer
--**
--**  Parameters:
--**  None
--**
--**  Returns:
--**  None
--**
--**-------------------------------------------------------------------------
--
--*/
_Clock_Init:
      add    -8, sp
      st.w  r11, 0[sp]
      st.w  r12, 4[sp]

      -- disable interrupt
      stsr  5, r11
      ori         0x80, r11, r11
      ldsr  r11, 5

      clr1  0, SYS[r0]              -- reset SYS register

      mov   r0, r11
      ld.b  PCC[r0], r12
      andi  0xf8, r12, r12
      or          r12, r11
```

```
      st.b  r11, PRCMD[r0]
      st.b  r11, PCC[r0]

      nop
      nop
      nop
      nop
      nop
      -- PLL start
      set1  0, PLLCTL[r0]
      -- PLL work
.if 1 -- fix bad code generated by Applilet
-- need to set r11 to some value before starting this loop!
      -- Lock 200 us
      movea 0x800, r0, r11
.endif
__CG_LOOP4:
      nop
      nop
      nop

      addi  -1, r11, r11
      cmp   r0, r11
      bnz   __CG_LOOP4
      set1  1, PLLCTL[r0]
      -- enable interrupt
      stsr  5, r11
      andi  0x7f, r11, r11
      ldsr  r11, 5
      -- pop
      ld.w  0[sp], r11
      ld.w  4[sp], r12
      add   8, sp
      --disable watchdog timer 2
      mov   0x1f, r11
      st.b  r11, WDTM2[r0]

      jmp [lp]
```

4.2.5 System_user.c

```
/*
******************************************************************************
**
**  This device driver was created by Applilet for the V850ES/FE2,
V850ES/FF2,V850ES/FG2
**  and V850ES/FJ2 32-Bit Single-Chip Microcontrollers
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
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**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
incurred
**  by customers or third parties arising from the use of this file.
**
```

```
**  Filename : system_user.c
**  Abstract : This file implements a device driver for the SYSTEM interrupt
service routine
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
**
**  Compiler:  NEC/CA850
**
*****************************************************************************
*/
/*
** ***************************************************************************
** Include files
** ***************************************************************************
*/

#include "macrodriver.h"
/*
** ***************************************************************************
** MacroDefine
** ***************************************************************************
*/
```

4.2.6 Timer.h

```
/*
*****************************************************************************
**
**  This device driver was created by Applilet for the V850ES/KJ1+,
V850ES/KG1+,
**  V850ES/KF1+ and V850ES/KE1+ 32-Bit Single-Chip Microcontrollers
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
**  NEC Electronics Corporation assumes no responsibility for any losses
**  incurred by customers or third parties arising from the use of this file.
**
**  Filename : timer.h
**  Abstract : This file implements a device driver for the timer module
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
*****************************************************************************
*/

#ifndef _MDTIMER_
#define _MDTIMER_

/*
** ****************************************************************************
```

```
**MacroDefine
** ****************************************************************************
*/
#define     TM_TMP0_CLOCK     0x0
#define     TM_TMP0_INTERVALVALUE   0x00
#define     TM_TMP0_INTERVALVALUE2  0x00
#define     TM_TMP0_ONESHOTOUTPUTCYCLE    0x00
#define     TM_TMP0_ONESHOTOUTPUTDELAY    0x00
#define     TM_TMP0_EXTTRIGGERCYCLE 0x00
#define     TM_TMP0_EXTTRIGGERDELAY 0x00
#define     TM_TMP0_PWMCYCLE  0x00
#define     TM_TMP0_PWMWIDTH  0x00
#define     TM_TMP0_CCR0COMPARE     0x00
#define     TM_TMP0_CCR1COMPARE     0x00
#define     TM00_Clock  0x0
#define     TM00_INTERVALVALUE      0x270f
#define     TM00_SQUAREWIDTH  0x270f
#define     TM00_PPGCYCLE     0x270f
#define     TM00_PPGWIDTH     0x00
#define     TM00_ONESHOTCYCLE 0x270f
#define     TM00_ONEPULSEDELAY      0x00
#define     TM01_Clock  0x0
#define     TM01_INTERVALVALUE      0x00
#define     TM01_SQUAREWIDTH  0x00
#define     TM01_PPGCYCLE     0x00
#define     TM01_PPGWIDTH     0x00
#define     TM01_ONESHOTCYCLE 0x00
#define     TM01_ONEPULSEDELAY      0x00
#define     TM02_Clock  0x0
#define     TM02_INTERVALVALUE      0x00
#define     TM02_SQUAREWIDTH  0x00
#define     TM02_PPGCYCLE     0x00
#define     TM02_PPGWIDTH     0x00
#define     TM02_ONESHOTCYCLE 0x00
#define     TM02_ONEPULSEDELAY      0x00
#define     TM03_Clock  0x0
#define     TM03_INTERVALVALUE      0x00
#define     TM03_SQUAREWIDTH  0x00
#define     TM03_PPGCYCLE     0x00
#define     TM03_PPGWIDTH     0x00
#define     TM03_ONESHOTCYCLE 0x00
#define     TM03_ONEPULSEDELAY      0x00
#define     TM04_Clock  0x0
#define     TM04_INTERVALVALUE      0x00
#define     TM04_SQUAREWIDTH  0x00
#define     TM04_PPGCYCLE     0x00
#define     TM04_PPGWIDTH     0x00
#define     TM04_ONESHOTCYCLE 0x00
#define     TM04_ONEPULSEDELAY      0x00
#define     TM05_Clock  0x0
#define     TM05_INTERVALVALUE      0x00
#define     TM05_SQUAREWIDTH  0x00
#define     TM05_PPGCYCLE     0x00
#define     TM05_PPGWIDTH     0x00
#define     TM05_ONESHOTCYCLE 0x00
```

```
#define     TM05_ONEPULSEDELAY      0x00
#define     TM50_Clock  0x5
#define     TM50_INTERVALVALUE      0x1e
#define     TM50_SQUAREWIDTH  0x1e
#define     TM50_PWMACTIVEVALUE     0x1e
#define     TM51_Clock  0x5
#define     TM51_INTERVALVALUE      0x1e
#define     TM51_SQUAREWIDTH  0x1e
#define     TM51_PWMACTIVEVALUE     0x1e
#define     TMH0_Clock  0x3
#define     TMH0_INTERVALVALUE      0x7c
#define     TMH0_SQUAREWIDTH  0x7c
#define     TMH0_PWMCYCLE     0x7c
#define     TMH0_PWMDELAY     0x3d
#define     TMH0_CARRIERDELAY 0x7c
#define     TMH0_CARRIERWIDTH 0x3d
#define     TMH1_Clock  0x3
#define     TMH1_INTERVALVALUE      0x7c
#define     TMH1_SQUAREWIDTH  0x7c
#define     TMH1_PWMCYCLE     0x7c
#define     TMH1_PWMDELAY     0x3d
#define     TMH1_CARRIERDELAY 0x7c
#define     TMH1_CARRIERWIDTH 0x3d


/*timer00 to 05,50,51,H0,H1 configurator initiation*/
void TM00_Init( void );

/*timer00 to 05 free running start,50,51,H0,H1 timer start*/
void TM00_Start( void );

/*timer00 to 05,50,51,H0,H1 timer stop*/
void TM00_Stop( void );
MD_STATUS TM00_ChangeTimerCondition(USHORT* array_reg,USHORT array_num);
__interrupt void MD_INTTM000( void );

/* added functions in timer_user.c for millisecond timer */
void SetMsecTimer(int time);  /* set the timer */
BOOL CheckMsecTimer(void);          /* check the timer */

#endif
```

4.2.7 Timer.c

```
/*
*****************************************************************************
**
**  This device driver was created by Applilet for the V850ES/KJ1+,
V850ES/KG1+,
**  V850ES/KF1+ and V850ES/KE1+ 32-Bit Single-Chip Microcontrollers
**
**  Copyright(C) NEC Electronics Corporation 2002-2004
**  All rights reserved by NEC Electronics Corporation
**
**  This program should be used on your own responsibility.
```

```
**  NEC Electronics Corporation assumes no responsibility for any losses
**  incurred by customers or third parties arising from the use of this file.
**
**  Filename : timer.c
**  Abstract : This file implements a device driver for the timer module
**  APIlib:  V850ESKX1H.lib V1.33 [24 Sep 2004]
**
  Device:  uPD70F3318Y
**
**  Compiler:  NEC/CA850
**
*****************************************************************************
*/

/*
** ***************************************************************************
** Include files
** ***************************************************************************
*/
#include "macrodriver.h"
#include "timer.h"
/*
** ***************************************************************************
**MacroDefine
** ***************************************************************************
*/
/*
**---------------------------------------------------------------------------
**
**  Abstract:
**    Initiate TM00, select founction and input parameter
**    count clock selection, INT init
**
**  Parameters:
**    None
**
**  Returns:
**    None
**
**---------------------------------------------------------------------------
*/
void TM00_Init( void )
{
      TMC00 = 0x0;                                    /* stop TM00 */
      ClrIORBit(PRM00, 0x3);
      ClrIORBit(SELCNT1, 0x1);

      SELCNT1 |= ( TM00_Clock&0x4)>>2;    /* internal count clock */
      PRM00 |=( TM00_Clock&0x3);

      /* INTTM000 setting */
      TM0IC00 = Lowest;
      SetIORBit(TM0IC00, 0x40);
      /* TM00 interval */
      ClrIORBit(CRC00, 0x01);
```

```
      CR000 = TM00_INTERVALVALUE;
      CR001 = 0xffff;
}

/*
**---------------------------------------------------------------------------
**
**  Abstract:
**    start the TM00 counter
**
**  Parameters:
**    None
**
**  Returns:
**    None
**
**
**---------------------------------------------------------------------------
*/
void TM00_Start( void )
{
      TMC00 = 0x0c;                        /* interval timer start */
      ClrIORBit(TM0IC00, 0x40);            /* enable INTTM000 */
}

/*
**---------------------------------------------------------------------------
**
**  Abstract:
**    stop the TM00 counter and clear the count register
**
**  Parameters:
**    None
**
**  Returns:
**    None
**
**---------------------------------------------------------------------------
*/
void TM00_Stop( void )
{
      TMC00 = 0x0;                               /* stop TM00 */
      SetIORBit(TM0IC00, 0x40);            /* disable INTTM000 */
}

/*
**---------------------------------------------------------------------------
**
**  Abstract:
**    Change TM00 condition.
**
**  Parameters:
**    USHORT*:     array_reg
**    USHORT:       array_num
**  Returns:
```

```
**      MD_OK
**      MD_ERROR
**
**---------------------------------------------------------------------------
*/
MD_STATUS TM00_ChangeTimerCondition(USHORT* array_reg,USHORT array_num)
{
   switch (array_num){
         case 2:
                  CR001=*(array_reg + 1);
         case 1:
                  CR000=*(array_reg + 0);
                  break;
         default:
                  return MD_ERROR;
         }
        return MD_OK;
}
```