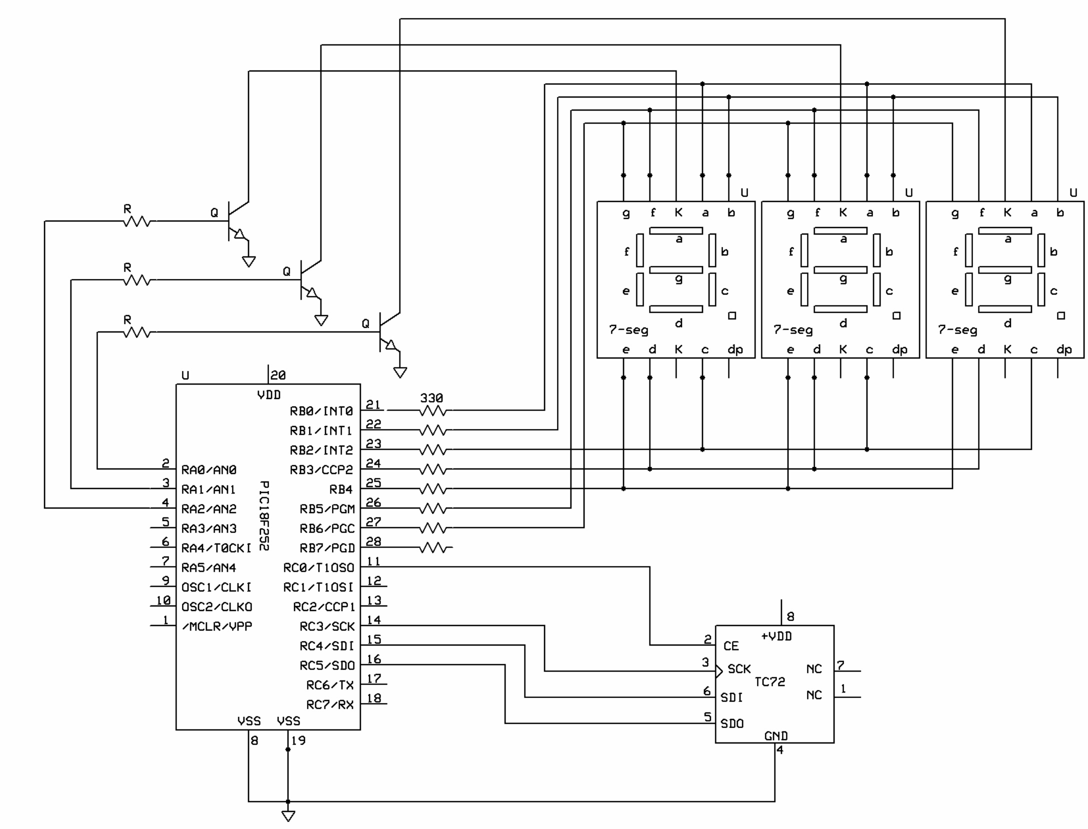
Problema (1h 30 min, 3,75 puntos)

Acabamos de ser contratados en una empresa que fabrica termómetros electrónicos. Para superar el periodo de contrato en prácticas nos han pedido que analicemos su producto estrella. Se trata de un circuito termómetro cuyo esquemático que se presenta a continuación. Este se basa en un sensor de temperatura de Microchip, el TC72, un microcontrolador PIC y una pantalla de tres displays 7 segmentos. Cada uno de los segmentos (a,b,c,d,e,f y g) es un diodo LED cuyo ánodo se conecta a un pin por segmento, y todos los cátodos se conectan al pin K.

Este es el esquemático que nos han facilitado, en el que no se ha representado ni las alimentaciones, ni el circuito de reloj (un cristal de 8MHz), ni el RESET por reducir la complejidad del mismo.



Para completar la descripción del sistema, nos han facilitado también alguna de las rutinas del software, las cuáles puede encontrar en las hojas adjuntas al problema.

El test que la empresa pide que superemos consta de las siguientes cuestiones:

1. Para el sensor, indicar a través de qué interfase hemos conectado el Microcontrolador y el TC72.

2. Para el display, ¿Cuál es la utilidad de las dos tablas definidas en el programa, display y 7segdecod?

3. Realiza el diagrama de flujo de la rutina **read_temp**. El diagrama debe mostrar claramente la función del programa, y especialmente la función de cada uno de los conjuntos de líneas de código que ha sido separadas del resto mediante líneas en blanco.

4. Para qué se utilizan cada una de las variables definidas en esta rutina, **read_temp**.

5. ¿En qué modo de funcionamiento opera el TC72?

6. ¿Cuál es la misión de las líneas del programa SSPBUF = 0x00?

7. Qué tiempo de espera implementa la rutina **wait_Xms()** ¿Por qué es necesario este tiempo de espera en el programa?

8. ¿Cuál seria el nombre adecuado para la etiqueta del pin PORTCbits.RC0 de forma que haga referencia a su función?

9. A partir del código presentado, ¿Qué interrupciones debe habilitar el bloque de configuración de **main()** ?

```
        ;CODIGO DEL TERMOMETRO termo72

char    display[3]   = {0x40, 0x20, 0x01};
char 7segdecod[10] = {0x3F, 0x06, 0x5B, 0x4F, 0x66, 0x79, 0x7D, 0x7F, 0x6F}


void disp7seg ( )
{
        while(1) {
                for(i=0; i < 3; i++) {
                        dummy1  =  Temp_buf[i];
                        PORTB = 7segdecod[dummy1];
                        PORTA = display[i];
                }
        }
}


void read_temp (char *ptr)
{
        char hi_byte, lo_byte, temp, *bptr;
        unsigned int result;
        bptr = ptr;

        PORTCbits.RC0 = 1;

        SSPBUF = 0x80;
        while(!SSPSTATbits.BF);
```

```
        temp = SSPBUF;

        SSPBUF = 0x11;
        while(!SSPSTATbits.BF);
        PORTCbits.RC0 = 0;
        temp = SSPBUF;

        wait_Xms();

        PORTCbits.RC0 = 1;

        SSPBUF = 0x02;
        while(!SSPSTATbits.BF);
        temp = SSPBUF;

        SSPBUF = 0x00;
        while(!SSPSTATbits.BF);
        hi_byte = SSPBUF;

        SSPBUF = 0x00;
        while(!SSPSTATbits.BF);
        lo_byte = SSPBUF;

        PORTCbits.RC0 = 0;

        if (hi_byte & 0x80) {
                result = hi_byte;
                result = ~result + 1;
                *ptr++ = 0x40;
        }
        else {
                temp   = result / 100;
                *ptr++ = temp;
                result -= temp*100;
        }

        temp   = result / 10;
        *ptr++ = temp;
        result -= temp*10;

        *ptr++ = result;

}

void wait_Xms(void)
{
        OpenTimer0(TIMER_INT_OFF & T0_16BIT & T0_SOURCE_INT &
                        T0_PS_1_32);
        TMR0 = 15535;
        INTCONbits.TMR0IF = 0;
        while(!INTCONbits.TMR0IF);
}
```

TC72 Datasheet

Features
• Temperature-to-Digital Converter
• SPI™ Compatible Interface
• 10-Bit Resolution (0.25°C/Bit)

General Description
The TC72 is a digital temperature sensor capable of reading temperatures from -55°C to +125°C. The TC72 has a 10-bit temperature sensor Analog-to-Digital Converter (ADC). The 10-bit ADC is scaled from -128°C to +127°C; therefore, the resolution is 0.25°C per bit. The ambient temperature operating range of the TC72 is specified from -55°C to +125°C.

This device features a four-wire serial interface that is fully compatible with the SPI specification and, therefore, allows simple communications with common microcontrollers and processors.

The TC72 can be used either in a Continuous Temperature Conversion mode or a One-Shot Conversion mode. The Continuous Conversion mode measures the temperature approximately every 150 ms and stores the data in the temperature registers. The TC72 has an internal clock generator that controls the automatic temperature conversion sequence. The automatic temperature sampling operation is repeated indefinitely until the TC72 is placed in a shutdown mode by a write operation to the Control register.

In contrast, the One-Shot mode performs a single temperature measurement and returns to the power saving shutdown mode.

The TC72 also features a shutdown mode for low power operation.

Temperature Data Format
Temperature data is represented by a 10-bit two's complement word with a resolution of 0.25°C per bit. The temperature data is stored in the Temperature registers in a two's complement format. The ADC converter is scaled from -128°C to +127°C, but the operating range of the TC72 is specified from -55°C to +125°C.

Example:
Temperature = 41.5°C
MSB Temperature Register= 00101001b = $2^5 + 2^3 + 2^0 = 32 + 8 + 1 = 41$
LSB Temperature Register = 10000000b = $2^{-1} = 0.5$

TABLE 4-1: REGISTERS FOR TC72

Register	Read Address	Write Address	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR/BOR
Control	00hex	80hex	0	0	0	One-Shot (OS)	0	1	0	Shutdown (SHDN)	05hex
LSB Temperature	01hex	N/A	T1	T0	0	0	0	0	0	0	00hex
MSB Temperature	02hex	N/A	T9	T8	T7	T6	T5	T4	T3	T2	00hex
Manufacturer ID	03hex	N/A	0	1	0	1	0	1	0	0	54hex

TABLE 3-2: TEMPERATURE REGISTER

D7	D6	D5	D4	D3	D2	D1	D0	Address/ Register
Sign	2^6	2^5	2^4	2^3	2^3	2^1	2^0	02H Temp. MSB
2^{-1}	2^{-2}	0	0	0	0	0	0	01H Temp. LSB

Control Register

The Control register is both a read and a write register that is used to select either the Shutdown, Continuous or One-Shot Conversion operating mode. The Temperature Conversion mode selection logic is shown in Table 4-2.

The Shutdown (SHDN) bit is stored in bit 0 of the Control register. If SHDN is equal to '1', the TC72 will go into the power-saving shutdown mode. At power-up, the SHDN bit is set to '1'. Thus, the TC72 is in the shutdown operating mode at startup. The shutdown mode disables the temperature conversion circuitry; however, the serial I/O communication port remains active.

A temperature conversion will be initialized by a Write operation to the Control register to select either the Continuous Temperature Conversion or the One-Shot operating mode. The temperature data will be available in the MSB and LSB Temperature registers approximately 150 ms after the Control register Write operation.

The Continuous Temperature Conversion mode is selected by writing a '0' to the SHDN bit of the Control register. The TC72 will perform a temperature conversion approximately every 150 ms.

The One-Shot mode is selected by writing a '1' into bit 4 of the Control register. The One-Shot mode performs a single temperature measurement and returns to the power-saving shutdown mode. After completion of the temperature conversion, the One-Shot bit (OS) is reset to '0' (i.e. "OFF"). The user must set the One-Shot bit to '1' to initiate another temperature conversion. Bits 1, 3, 5, 6 and 7 of the Control register are not used by the TC72.

TABLE 4-2: CONTROL REGISTER TEMPERATURE CONVERSION MODE SELECTION

Operational Mode	One-Shot (OS) Bit 4	Shutdown (SHDN) Bit 0
Continuous Temperature Conversion	0	0
Shutdown	0	1
Continuous Temperature Conversion (One-Shot Command is ignored if SHDN = '0')	1	0
One-Shot	1	1

Serial Bus Interface

The serial interface consists of the Chip Enable (CE), Serial Clock (SCK), Serial Data Input (SDI) and Serial Data Output (SDO) signals. The TC72 operates as a slave and is compatible with the SPI bus specifications. The serial interface is designed to be compatible with the Microchip PICmicro® family of microcontrollers.
The **CE input** is used to select the TC72 when multiple devices are connected to the serial clock and data lines. The CE is active-high, and data is written to or read from the device, when CE is equal to a logic high voltage. The SCK input is disabled when CE is

low. The rising edge of the CE line initiates a read or write operation, while the falling edge of CE completes a read or write operation.

The **SCK input** is provided by the external microcontroller and is used to synchronize the data on the SDI and SDO lines. The SDI input writes data into the TC72's Control register, while the SDO outputs the temperature data from the Temperature register and the status of Shutdown bit of the Control register.

The TC72 has the capability to function with either an active-high or low SCK input. The SCK inactive state is detected when the CE signal goes high, while the polarity of the clock input (CP) determines whether the data is clocked and shifted on either the rising or falling edge of the system clock.

Each data bit is transferred at each clock pulse, and the data bits are clocked in groups of eight bits, as shown in Figure 3-3.

The address byte is transferred first, followed by the data. A7, the MSb of the address, determines whether a read or write operation will occur. If A7 = '0', one or more read cycles will occur; otherwise, if A7 = '1', one or more write cycles will occur.

Data can be transferred either in a single byte or a multi-byte packet, as shown in Figure 3-3. In the 3-byte packet, the data sequence consists of the MSb temperature data, LSb temperature data, followed by the Control register data. The multi-byte read feature is initiated by writing the highest address of the desired packet to registers. The TC72 will automatically send the register addressed and all of the lower address registers, as long as the Chip Enable pin is held active.

Escritura en registros y Lectura de resultados del TC72

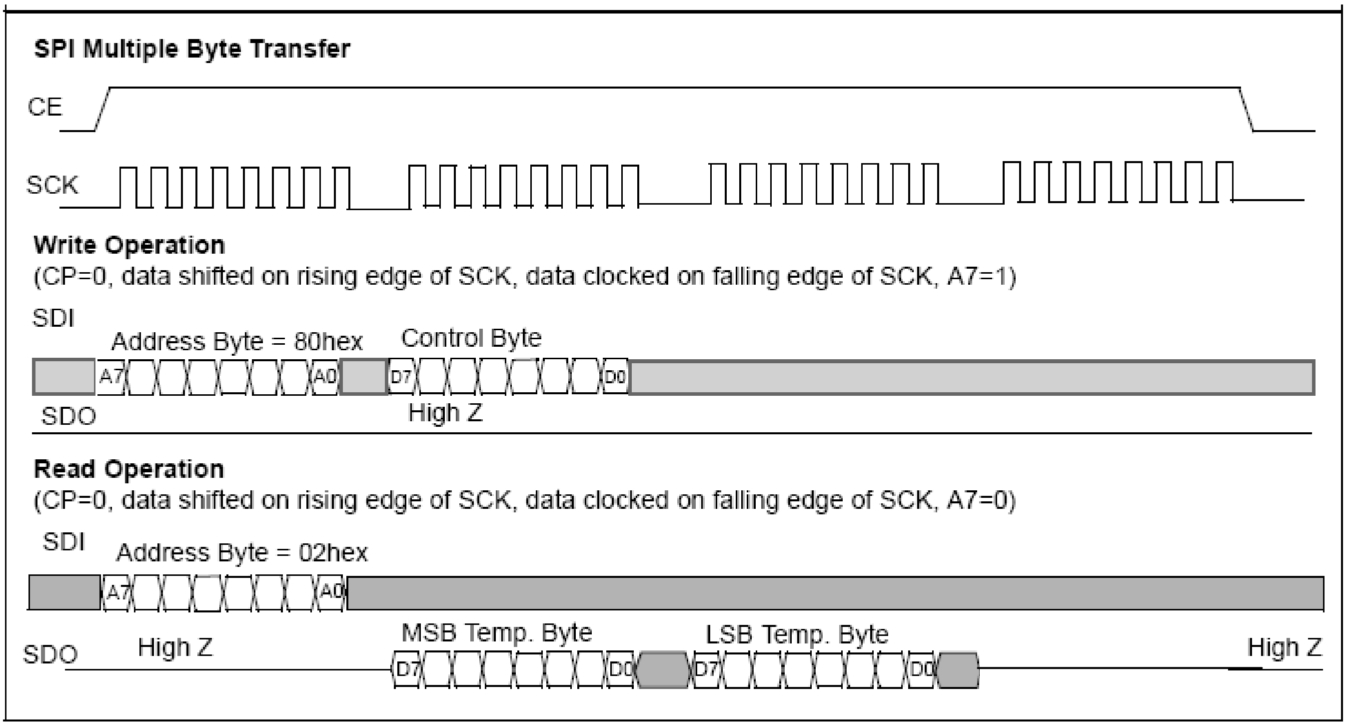


FIGURE 3-3: *Serial Interface Timing Diagrams (CP=0).*