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# TEMPERATURE COMPENSATED REAL TIME CLOCK REFERENCE DESIGN KIT USER'S GUIDE

## 1. Kit Contents

- Temperature Compensated RTC Evaluation Board
- AC to DC Power Adapter
- Straight DB9 serial cable (male-female)
- Straight DB25 parallel cable (male-male)
- Quick-start Guide
- Reference Design Kit CD-ROM containing the following items:
  - Temperature Compensated Real Time Clock Reference Design Programmer's Guide (AN293) and associated software (AN293SW.zip).
  - Keil Software 8051 Development Tools (evaluation assembler, 2 kB limited compiler, and linker).

## 2. Requirements

The Temperature Compensated Real Time Clock Reference Design Kit is a completely independent evaluation platform with preloaded firmware. The following are the only requirements to evaluate this reference design without any modifications to the firmware.
PC with the following features:

- Operating system: Windows 2000/XP/Server2003
- One available serial port
- One available parallel port (required to evaluate the optional SMBus/$I^2C$ interface)

Although the instructions in this user's guide are written for a PC running the Windows OS, PCs with other operating systems can also be used to evaluate this design as long as a serial port and a terminal program are available.
In order to modify, rebuild, and download code into the C8051F300 MCU on this evaluation board, the following additional items are required but not included in this kit:

- USB Debug Adapter and USB cable, or Serial Adapter and RS-232 serial cable
- Full version of Keil Software C51 assembler, compiler, and linker

The C8051F300DK Development Kit includes the USB Debug Adapter and USB cable along with a C8051F300-TB Target Board.

**Note:** A full version of the Keil tool chain is required in order to modify and recompile the code provided with this reference design because the code size is greater than the evaluation tool chain's code size limits. Alternatively, the source code can be ported to work with other 8051 tool chains that are supported by the Silicon Labs IDE. For a list of currently supported tool chains, please refer to the following MCU Knowledge Base Article: http://portal.knowledgebase.net/article.asp?article=173563&p=4120

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## 3. Kit Overview

The Temperature Compensated Real Time Clock (TC-RTC) Reference Design Kit includes an evaluation board that utilizes a Silicon Laboratories C8051F300 Mixed Signal Microcontroller. This kit offers the following features:

- Low-cost Temperature Compensated Real Time Clock and Calendar
- 56-byte General Purpose Non-Volatile RAM
- RS-232 Serial Interface
- Optional SMBus/$I^2$C Interface
- Full source code for the TC-RTC firmware is included

The board is pictured in Figure 1, with the major components labeled. The MCU on the board is preloaded with the TC-RTC firmware with UART interface, and the included CD-ROM contains the firmware source code. More information about this reference design can be found in "AN293: Temperature Compensated Real Time Clock Reference Design Programmer's Guide." The following sections demonstrate the features of this reference design.
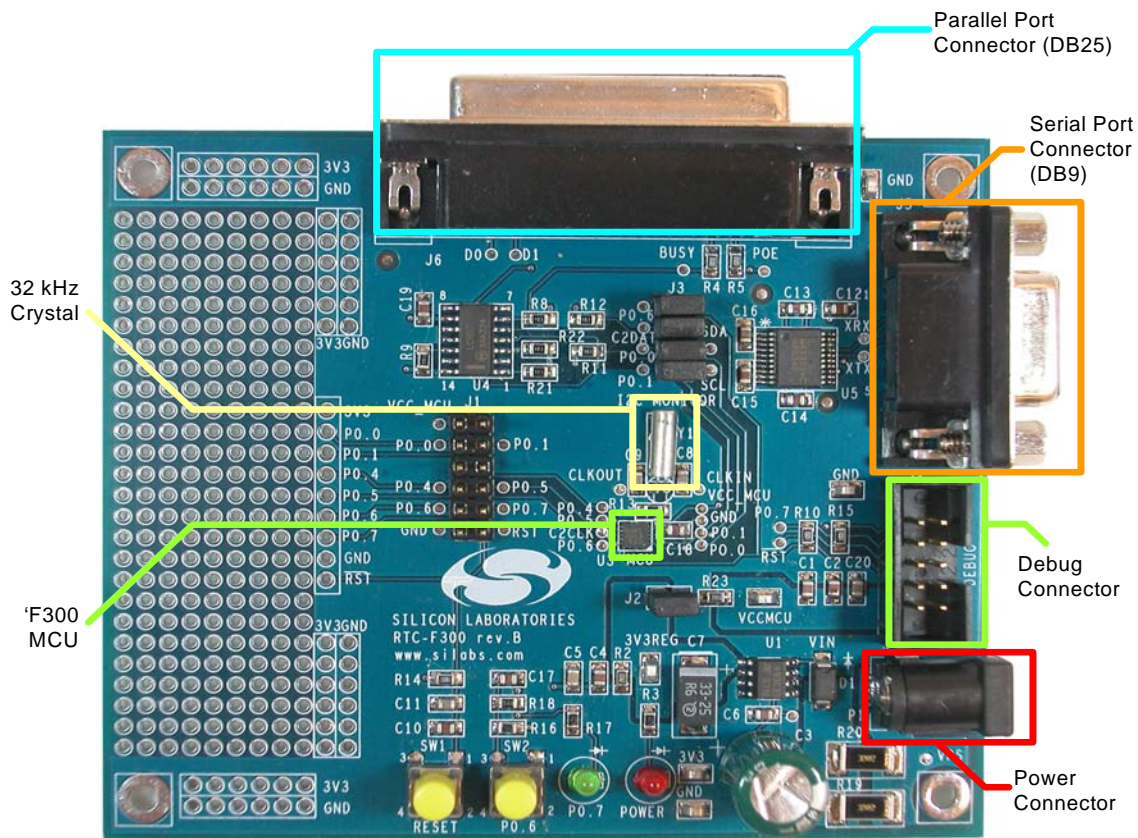


**Figure 1. Temperature Compensated RTC Evaluation Board**

# 4. TC-RTC Evaluation Board

The functions of the major components on the TC-RTC Evaluation Board that are labeled in Figure 1 are listed below. The board schematic and bill of materials are shown in Sections 7 and 8, respectively.

- C8051F300 MCU (U3)—Microcontroller with firmware to perform the TC-RTC function.
- 32.768 kHz Crystal (Y1)—This low-cost watch crystal is used for time keeping.
- DB9 connector (J5)—This is for the serial RS-232 connection.
- DB25 connector (J6)—This is for the optional parallel connection with SMBus interface.

In addition to these, a RS-232 transceiver and a buffer are used for the serial and SMBus interfaces, respectively.

# 5. TC-RTC Firmware

The clock accuracy of a time-keeping system based on a resonating quartz crystal is primarily affected by the variation of crystal frequency with respect to temperature. Figure 2 shows a plot of the variation of crystal frequency versus temperature. From the parabolic curve, it can be seen that the RTC will *lose* time if the temperature is increased or decreased from the room temperature value (25 °C). The RTC will never have a positive error caused by temperature variations (i.e., *gain* time) because the maximum frequency is at room temperature.
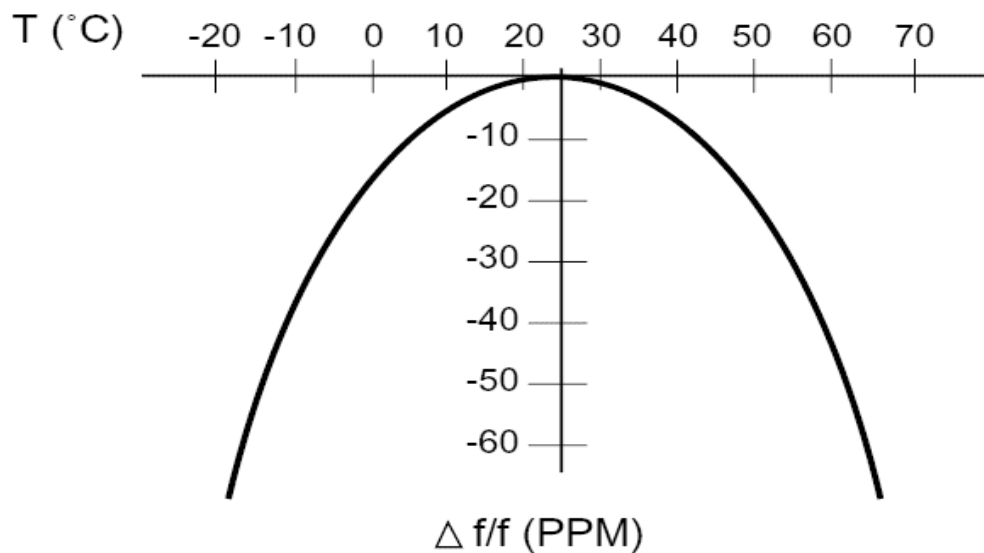


**Figure 2. Crystal Frequency Variation Due to Temperature**

The TC-RTC firmware running on the C8051F300 MCU eliminates this time loss because of temperature variations. It uses the on-chip ADC and temperature sensor to measure the temperature every minute and compensate for the lost time at the end of the day by adding the accumulated error to the RTC's reported time. This is explained in more detail in "AN293: Temperature Compensated Real Time Clock Reference Design Programmer's Guide".

The time maintained by the TC-RTC can be accessed via two interfaces—a RS-232 serial interface via a DB9 connector and an SMBus interface via a DB25 connector. The preloaded firmware is built to work with the RS-232 serial interface. Also included in the AN293SW.zip package is a pre-built OMF file, which enables the SMBus interface to the RTC when loaded into the device. The AN293SW.zip package contains the full source code as well.

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## 6. TC-RTC Demonstration

The following step-by-step demonstration explains the various features and capabilities of this reference design. There are two interfaces available for the RTC—UART and SMBus, which are demonstrated in sections 6.1 and 6.2, respectively.

### 6.1. UART Interface Demonstration

The TC-RTC Evaluation Board comes preloaded with firmware that enables the UART interface. The following sections show how to set up and use this interface.

#### 6.1.1. PC Software Setup

On the PC, set up HyperTerminal to use the COM port at 9600 baud, 8-N-1, and no flow control. Detailed instructions to set this up are shown below.
1. Launch HyperTerminal from your Start Menu: Start Menu→Programs→Accessories→Communications→ HyperTerminal.
2. Type any name for the new connection, and click OK.
3. In the"Connect using:" drop-down list, Choose "COM1", or if you have multiple COM ports, choose the one you want to use.
4. Set up the COM1 Properties dialog as shown in Figure 3, and click OK.
5. Select "File→Properties→Settings→ASCII Setup". Check the box marked "Echo typed characters locally", and click OK. See Figure 4.
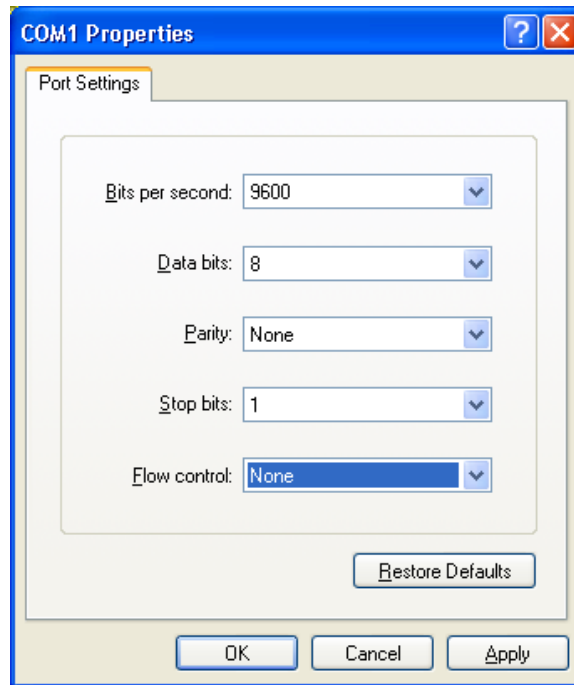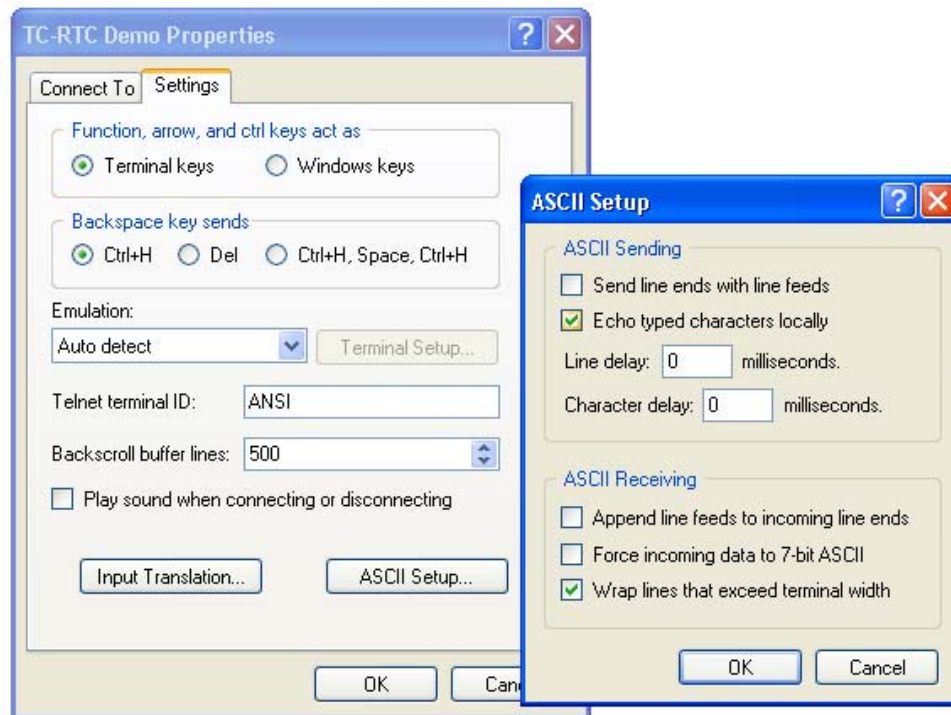


**Figure 3. HyperTerminal Settings**

**Figure 4. HyperTerminal ASCII Setup**

### 6.1.2.  Hardware Setup

1.  Connect the provided DB9 serial cable between the PC's serial port and the TC-RTC evaluation board connector J5.
2.  Apply power to the evaluation board using the provided dc power adapter.

### 6.1.3.  Interacting with the TC-RTC

1.  After the board is powered on for the first time, the board firmware will perform a temperature sensor/ADC offset calibration. For valid calibration, a soak period is required before the calibration is done. Wait for 15 seconds for calibration to complete. At the end of calibration, the green LED on the board will start blinking at a 1 Hz rate.
2.  HyperTerminal should now be displaying initial date, time and temperature information from the board. You can program the current date and time data into the board. This data should be trans-coded to the format expected by the device firmware. Refer to "Appendix B—TC-RTC: Implementation Details" on page 12 for the data format. Note that the AM/PM information is encoded in the same byte as the hour. Here are some examples:

    06:31:09 PM, Thursday, May 04, 2006→09 31 66 04 04 05 06
    11:05:39 AM, Saturday, December, 08, 1979→39 05 51 06 08 12 79
3.  Type the "s" command to *toggle off* the auto-display mode that displays the time once every second. Note that commands should be only in lower case.
4.  Type the following "w" command (*write*) to program the device with a new time and date. See "Appendix A—TC-RTC: Supported Commands" on page 11 for command formats.

    w000709316604040506
5.  Type the "r" command (*read*) to get the current time and date information from the device.

    r0007
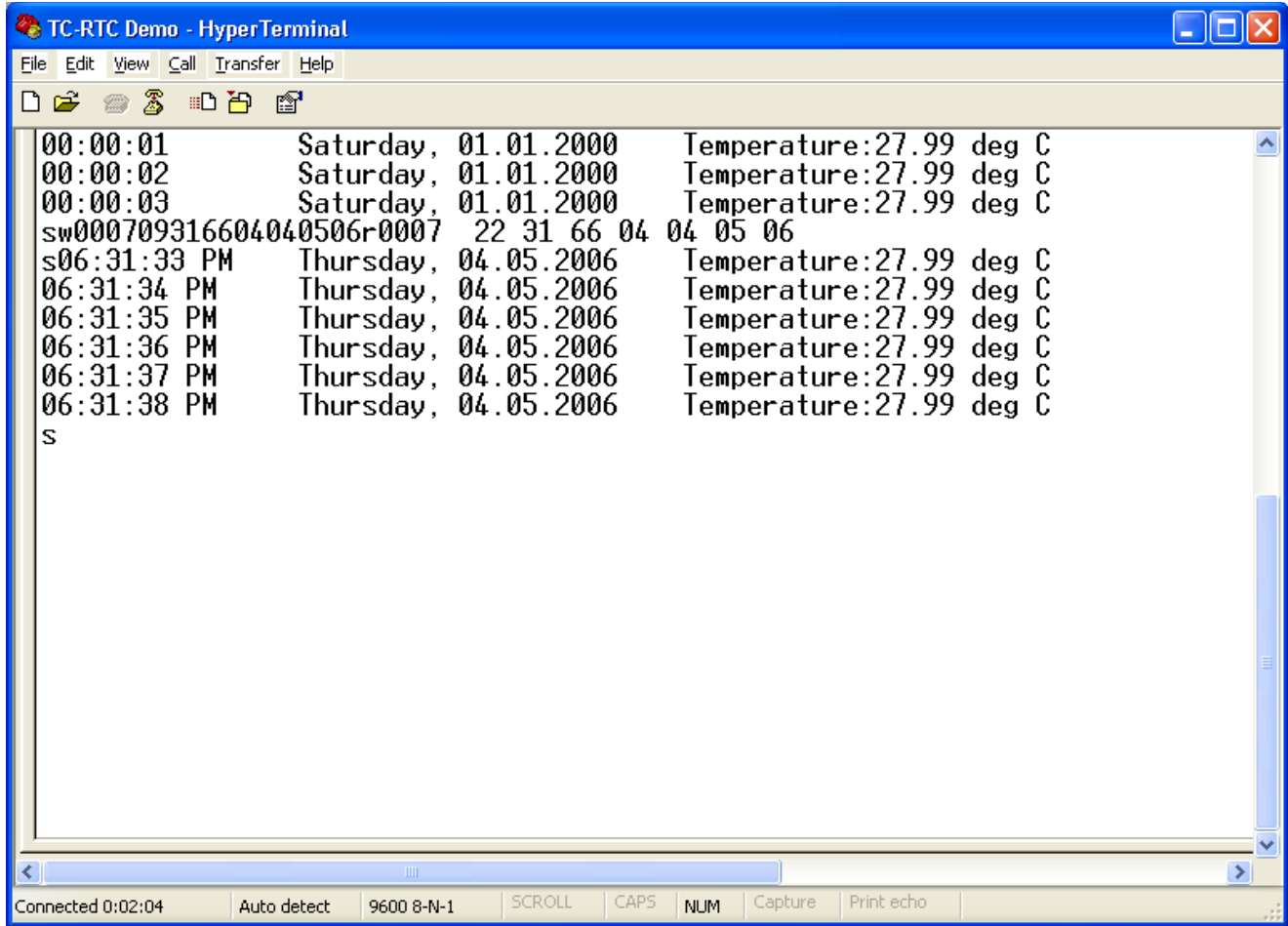6.  Type the "s" command to *toggle on* the auto-display mode.

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**Figure 5. Interacting with the TC-RTC—HyperTerminal Session**

An index of all supported commands is available in "Appendix A—TC-RTC: Supported Commands" on page 11. Detailed information about this reference design is contained in "AN293: Temperature Compensated Real Time Clock Reference Design Programmer's Guide".

## 6.2. SMBus Interface Demonstration

The TC-RTC Evaluation Board can be loaded with firmware that can enable an SMBus/I$^2$C interface. This is described in the following sections.

### 6.2.1. Firmware Download

The TC-RTC Evaluation Board comes preloaded with firmware that enables the UART interface. In order to enable the SMBus interface, alternate firmware has to be loaded on the device. The steps in this section will guide you through downloading the TC-RTC firmware with SMBus interface to the TC-RTC evaluation board.

1. Install the Silicon Laboratories IDE from the Reference Design Kit CD. Launch the IDE by choosing "Start Menu→All Programs→Silicon Laboratories→Silicon Laboratories IDE". If you need more information about installing and using the IDE, please refer to the C8051F300DK Development Kit User's Guide, which is available on this web page:

   http://www.silabs.com/tgwWebApp/public/web_content/products/Microcontrollers/en/C8051F300DK.htm

2. Depending on which type of debug adapter you have, set up the hardware as shown in one of the two diagrams below (Figure 4, Figure 5). Consult the C8051F300DK User's Guide if you need detailed instructions.
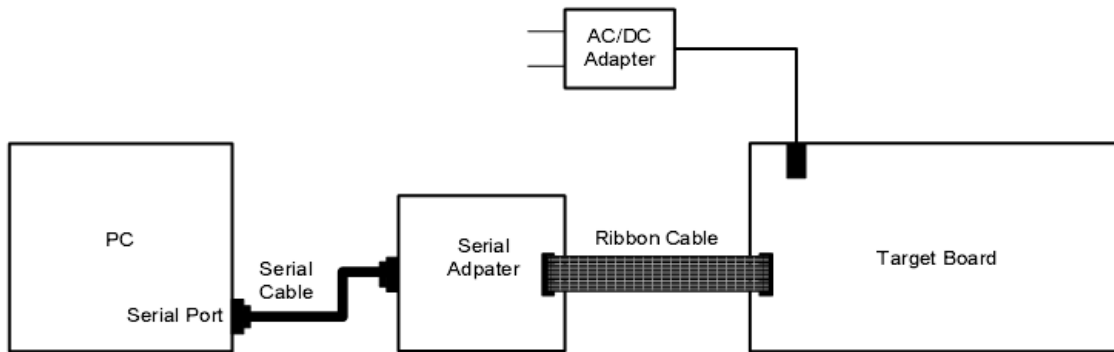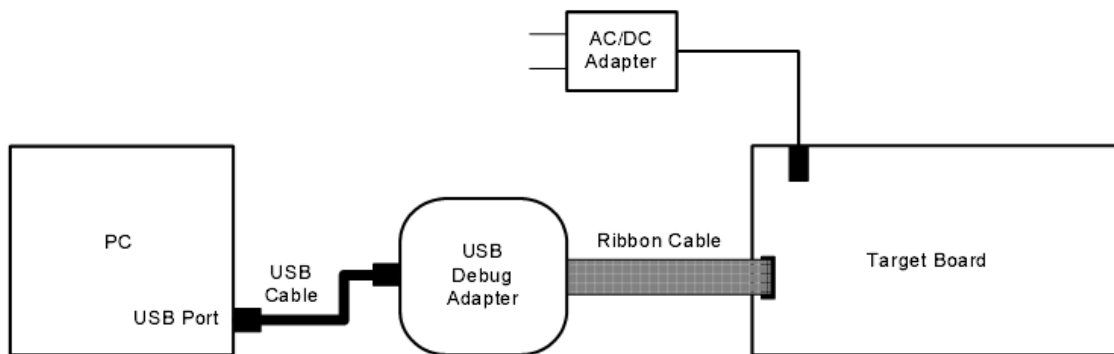
**Figure 6. Hardware Setup using a Serial Adapter**



**Figure 7. Hardware Setup using a USB Debug Adapter**

3. Before connecting to the target device, several connection options may need to be set. Open the "Connection Options" window by selecting "Options→Connection Options..." in the IDE menu. First, select the adapter that you are using in the "Serial Adapter" section. Next, the correct "Debug Interface" must be selected. C8051F30x family devices use the Silicon Labs 2-wire (C2) debug interface. Once these selections are made, click the OK button to close the window.

4. Click the "Connect" button in the toolbar or select "Debug→Connect" from the menu to connect to the device. You will see the text "Target: C8051F300" in the status bar of the IDE if the connection was successful.

5. Choose the "Project→Download Object File…" option. This shows a "Download" dialog. Click the "Browse" button and select the TC-RTC firmware pre-linked OMF file from this path:
C:\Silabs\MCU\TemperatureCompensated_RTC_RD\Firmware\TEMPCOMPRTC_RD_SMBUS.OMF

6. Click the "Download" button to download this firmware to the 'F300 device. You will see the text "Download successful" in the Build window if the firmware was downloaded successfully.

7. Disconnect the dc power adapter and the ribbon cable from the target board.

## 6.2.2. Hardware Setup

1. Connect the DB25 parallel cable provided with the kit between the PC's parallel port (printer port) and the 25-pin connector on the TC-RTC Evaluation board (J6).

2. Apply power to the board by connecting the dc power adapter.

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### 6.2.3. Interacting with the Windows SMBus Test Software

The TC-RTC Evaluation Board with the SMBus firmware enables an SMBus/I$^2$C interface to the RTC. In order to test this interface, PC software is provided that emulates an SMBus master via the PC's parallel port.

1. The PC Software is installed as part of the TC-RTC RD installation from the Reference Design Kit CD. Launch this by selecting the following: Start Menu→All Programs→Silicon Laboratories→TC-RTC SMBus Test.

2. Make sure that the green LED is blinking on the board, and then click the "Refresh All" button. This updates all the values shown.

3. Modify any value(s) that you would like to modify, and click the corresponding "Write", "Write NVRAM", or "Write Selected" button. This will write the value(s) to the board.

4. Clicking the "Read" button will read the current values from the board.

5. Check the "Auto-refresh Time/Date" check box to automatically update values every second. Note that when this is checked, the other read/write buttons are disabled.
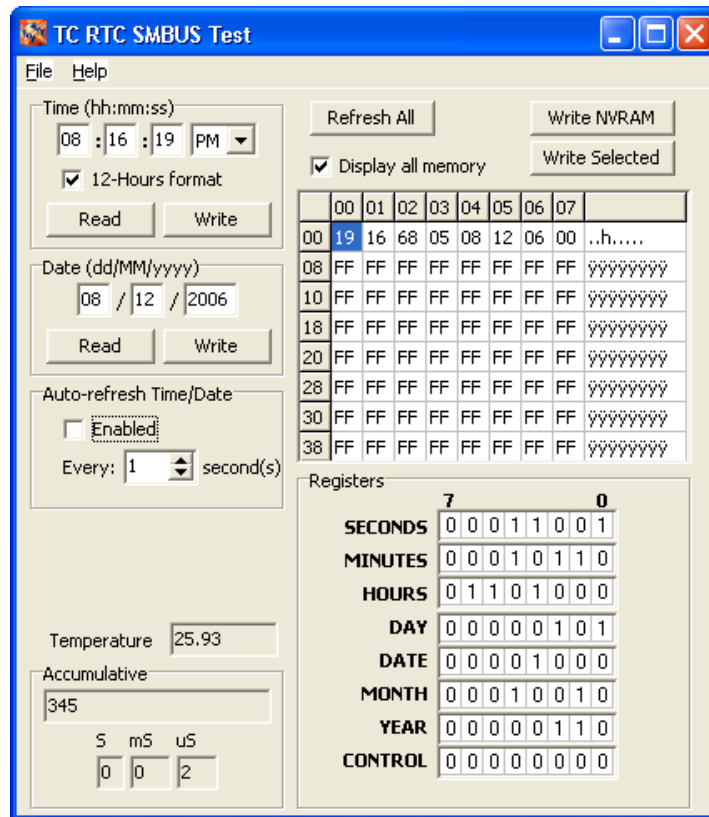


**Figure 8. TC-RTC SMBus Interface Test Software**

This PC software is provided solely for test and demonstration purposes. In a real application, the 'F300 device with the TC-RTC firmware is meant to be connected to other microcontrollers that have an SMBus interface. Refer to "AN293: Temperature Compensated Real Time Clock Reference Design Programmer's Guide" for more details on the SMBus interface implementation.

## 7. Schematic

Figure 9. TC-RTC Evaluation Board—Schematic
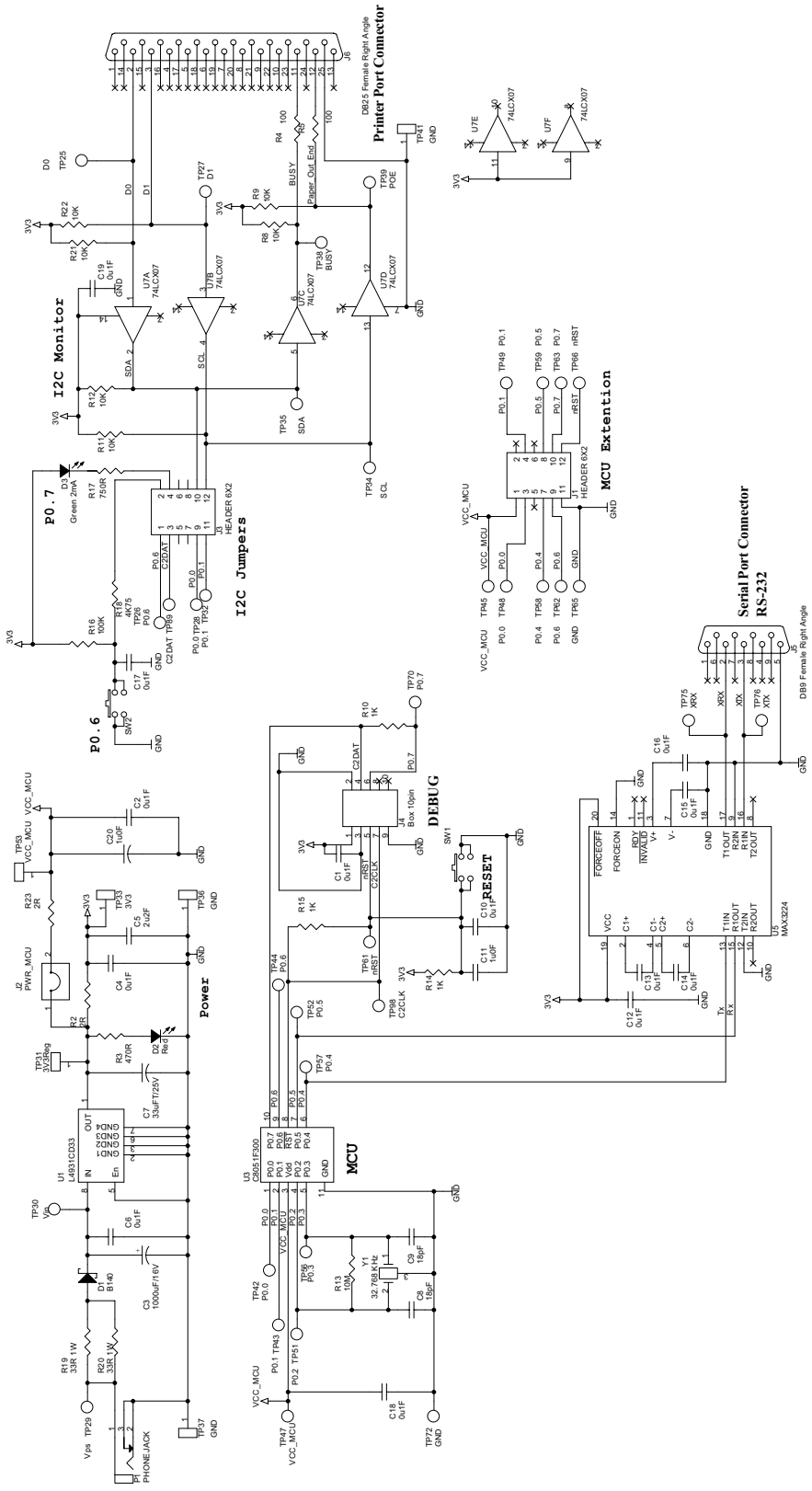
Note :
1. All resistors are 0.125W if another is not market on the scheme.
2. All resistors 0805 footprints if another is not market on the scheme.
3. All ceramic capacitors are X7R type and 0805 footprint if another is not market on the scheme.

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## 8. Bill of Materials

| Item | Qty | Reference | Value | Type | Manufacturer | P/N | Footprint |
|---|---|---|---|---|---|---|---|
| 1 | 13 | C1,C2,C4,C6,C10 C12,C13,C14,C15 C16,C17,C18,C19 | 0u1F | X7R | AVX | 0805YC104MAT2A | 0805 |
| 2 | 2 | C11,C20 | 1u0F | X7R | AVX | 0805YC105MAT2A | 0805 |
| 3 | 1 | C3 | 1000uF/16V | Electrolit | SANYO | 16MV1000FA | CAPMV-FA_10_125 |
| 4 | 1 | C7 | 33uT/25V | Tantalum | Vishay | 293D336X9025D2T | Case-D |
| 5 | 1 | C5 | 2u2F | X7R | | 0805YC225MAT2A | 0805 |
| 6 | 2 | C8,C9 | 18pF | NPO | AVX | 0805YA180MAT2A | 0805 |
| 7 | 1 | D1 | B140 | | Diodes Inc. | B140 | SMA |
| 8 | 1 | D2 | Red | | Kingbright | L-7104EC | LED_3mm |
| 9 | 1 | D3 | Green 2mA | | Kingbright | L-934LGD | LED_3mm |
| 10 | 1 | J1 | HEADER 6X2 | | Weitronics | 144-11-012-10-10 | HED6x2 |
| 11 | 1 | J2 | HEADER 2 | | Weitronics | 143-11-002-10-10 | HED2 |
| 12 | 1 | J3 | HEADER4X2 | | Weitronics | 144-11-008-10-10 | HED4x2 |
| 13 | 1 | J4 | Box 10pin | | Molex | 87256-1011 | BOX5x2 |
| 14 | 1 | J5 | DB9 Female RA | D-Type | Kycon | K22-E9S-NJ | d_type_9P |
| 15 | 1 | J6 | DB25Female RA | D-Type | Kycon | K22-E25S-NJ | d_type_25P |
| 16 | 1 | P1 | PHONEJACK | | Kycon | RTC Commp | CONPWR |
| 17 | 2 | R2,R23 | 2R | | AVX | CR-21-200J-T | 0805 |
| 18 | 2 | R4,R5 | 100R | | AVX | CR-21-101J-T | 0805 |
| 19 | 1 | R3 | 470R | | AVX | CR-21-471J-T | 0805 |
| 20 | 3 | R10,R14,R15 | 1K | | AVX | CR-21-102J-T | 0805 |
| 21 | 1 | R16 | 100K | | AVX | CR-21-105J-T | 0805 |
| 22 | 6 | R8,R9,R11,R12,R 21,R22 | 10K | | AVX | CR-21-104J-T | 0805 |
| 23 | 1 | R13 | 10M | | AVX | CR-21-107J-T | 0805 |
| 24 | 1 | R17 | 750R | | AVX | CR-21-751J-T | 0805 |
| 25 | 1 | R18 | 4K75 | | AVX | CR-21-4751J-T | 0805 |
| 26 | 2 | R19,R20 | 33R | | YAGEO | RC2512-330 | 2512 |
| 27 | 2 | SW1,SW2 | PUSHBUTTON | | Bourns | SDTX-610 | PB-TC0112 |
| 28 | 6 | TP31,TP33,TP36, TP37,TP41,TP53 | Test point | SMT | Keystone | 5015 | SMT-TP |
| 29 | 1 | U1 | L4931CD33 | | STG | L4931CD33 | SO-8 |
| 30 | 1 | U3 | C8051F300 | | Silicon Labs | C8051F300 | QFN-11 |
| 31 | 1 | U4 | 74LCX07 | | National | LM339 | SO-14 |
| 32 | 1 | U5 | MAX3224 | | Maxim | MAX3224E | SSOP-20 |
| 33 | 1 | Y1 | 32.768 kHz | | Gollege | SM26F-A | GWX-38 |

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## APPENDIX A—TC-RTC: SUPPORTED COMMANDS

## TC-RTC Firmware with UART Interface

The TC-RTC firmware with UART interface supports a set of commands to read/write date and time. The supported commands along with explanations are listed below:

- s                    – Toggles auto-display mode that displays time once every second.
- r xx yy          – Read yy bytes starting at address xx.
- w xx yy data   – Write yy bytes starting at address xx.

**Notes:**
1. The commands are case-sensitive. Only lower-case letters are accepted.
2. The addresses should be in decimal format (e.g., address 0x1F is entered as 31).
3. See "Appendix B—TC-RTC: Implementation Details" for information on how the RTC register data is formatted.

### Write Command Examples

- Date/Time: 11:05:39 AM, Saturday, December, 08, 1979→39 05 51 06 08 12 79
  w000739055106081279
- Time: 21: 48: 22→22 48 21
  w0003224821
- Day: Tuesday→02
  w030102
- NVRAM data write: 01 02 03 starting at address 0x1F (31)→31 01 02 03
  w3103010203

### Read Command Examples

- Date/Time: r0007
- NVRAM (all 56 bytes): r0856
- NVRAM (4 bytes starting at address 26): r2604

## TC-RTC Firmware with SMBus Interface

The TC-RTC firmware with the SMBus interface implements a SMBus Slave device with a Slave Address of 0xD0. The device operates in one of two modes: Slave Receiver Mode or Slave Transmitter Mode. In Slave Receiver Mode, it receives address and data from the Master and writes it to the RTC or NVRAM registers. In Slave Transmitter Mode, it sends data from the RTC or NVRAM registers to the Master. Refer to "AN293: Temperature Compensated Real Time Clock Reference Design Programmer's Guide" for more details on the SMBus interface implementation.

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## APPENDIX B—TC-RTC: IMPLEMENTATION DETAILS

## UART Communication Parameters

- Baud rate: 9600 bps
- Data format: 8 data bits, 1 stop bit, no parity
- Flow control: None

## RTC and NVRAM Registers—Data Format

| Address | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 | Range |
|---------|------|------|------|------|------|------|------|------|-------|
| 00H | CH | Seconds | | | | | | | 00-59 |
| 01H | 0 | Minutes | | | | | | | 00-59 |
| 02H | 0 | 12 / 24 | A/P | Hours | | | | | 01-12 01-23 |
| 03H | 0 | 0 | 0 | 0 | 0 | Day of Week | | | 1-7 |
| 04H | 0 | 0 | Date | | | | | | 01-31 |
| 05H | 0 | 0 | 0 | Month | | | | | 01-12 |
| 06H | Year | | | | | | | | 00-99 |
| 07H | Control (Reserved) | | | | | | | | |
| 08H | NVRAM 56 x 8 | | | | | | | | |
| 3FH | (Stored in non-volatile Flash Memory) | | | | | | | | |

**Figure 10. RTC and NVRAM Registers—Data Format**

**Notes:**
1. The contents of the time and calendar registers are in binary coded decimal (BCD) format.
2. The Clock Halt (CH) bit, when set to zero, will disable the RTC.
3. The 12/24 bit selects 12-hour mode if set to one.
4. In 12-hour mode, the AM/PM bit selects "PM" if set to one. In 24-hour mode, this bit is the second 10-hour bit (20-23 hours).

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# NOTES:

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