TI Designs
ULP Temperature Compensated RTC on MSP430F6736 Design Guide

TI Designs

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Design Resources

TIDM-TEMPCOMPENSATED-RTC	Tool Folder Containing Design Files
MSP430F6736	Product Folder
SN65HVD3082E	Product Folder
UA78L05	Product Folder

TI E2E™ Community

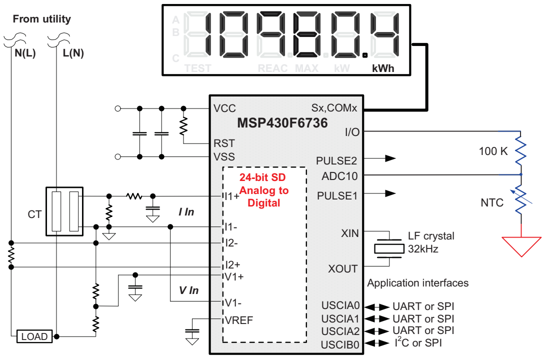
ASK Our E2E Experts
WEBENCH® Calculator Tools

Design Features

- On-Chip RTC_C Module and ADC10 for Ultra-Low Power and High-Accuracy RTC Calendar
- Reduces Cost of E-Meter Application
- High-Integration Chip a Solution to Single-Chip Electricity Meters

Featured Applications

- Smart E-Meter
- Single-Phase E-Meter
- Three-Phase E-Meter
- High-Accuracy RTC



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1 Key System Specifications

The RTC_C module in MSP430F673x functions as the real-time clock (RTC) in smart meters. RTC_C features include the following:

- Real-time clock and calendar mode providing seconds, minutes, hours, day of week, day of month, month, and year (including leap year correction)
- Protection for real-time-clock registers
- Interrupt capability
- Selectable binary coded decimal (BCD) or binary format
- Programmable alarms
- Real-time clock calibration for crystal offset error
- Real-time clock compensation for crystal temperature drifts
- Operation in LPM3.5
- Operation from a separate voltage supply with programmable charger

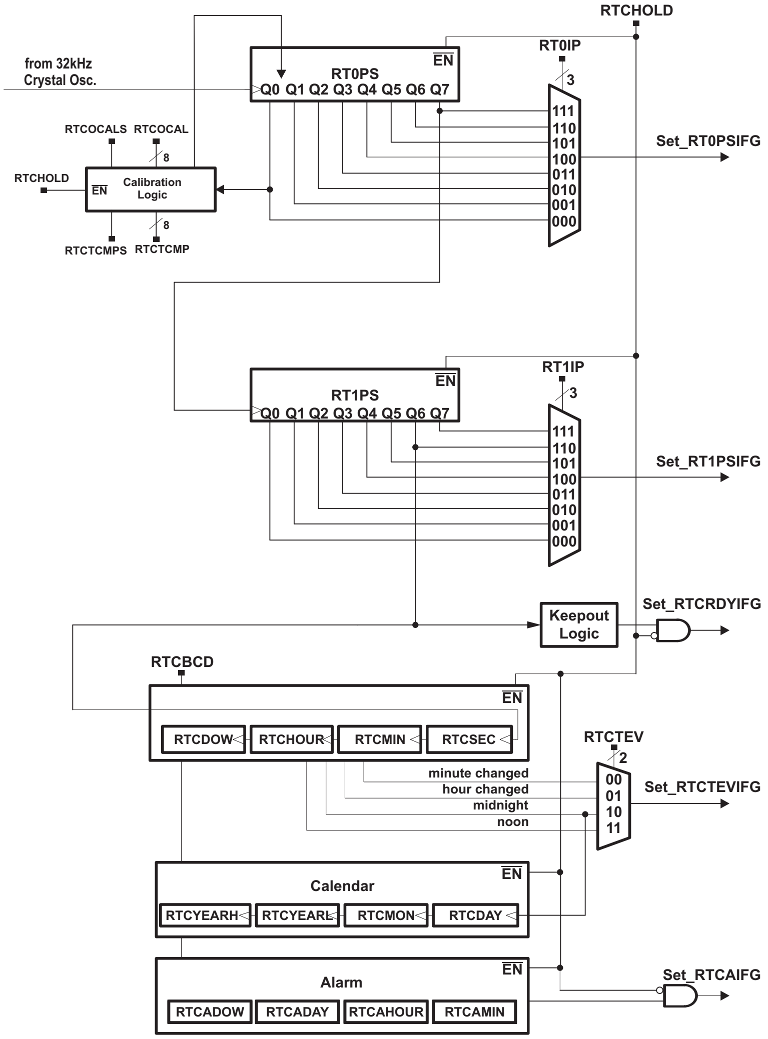


Figure 1. RTC_C Block Diagram

2 System Description

This report introduces the methodology to implement an ultra-low-power real-time clock (RTC) with temperature compensation functions in MSP430F6736. This report describes the crystal's temperature characteristics to use MSP430F6736's RTC_C module plus software to implement an ultra-low-power RTC, with an automatic temperature compensation feature and second ticks generation function. This report finally builds up a reference code that runs in MSP430F6736 and provides test results.

2.1 *MSP430F6736*

The MSP430F67xx series are microcontroller configurations with three high-performance 24-bit sigma-delta A/D converters, a 10-bit analog-to-digital (A/D) converter, four enhanced universal serial communication interfaces (three eUSCI_A and one eUSCI_B), four 16-bit timers, a hardware multiplier, direct memory access (DMA), a real-time clock module with alarm capabilities, an LCD driver with integrated contrast control, an auxiliary supply system, and up to 72 I/O pins in 100-pin devices and 52 I/O pins in 80-pin devices.

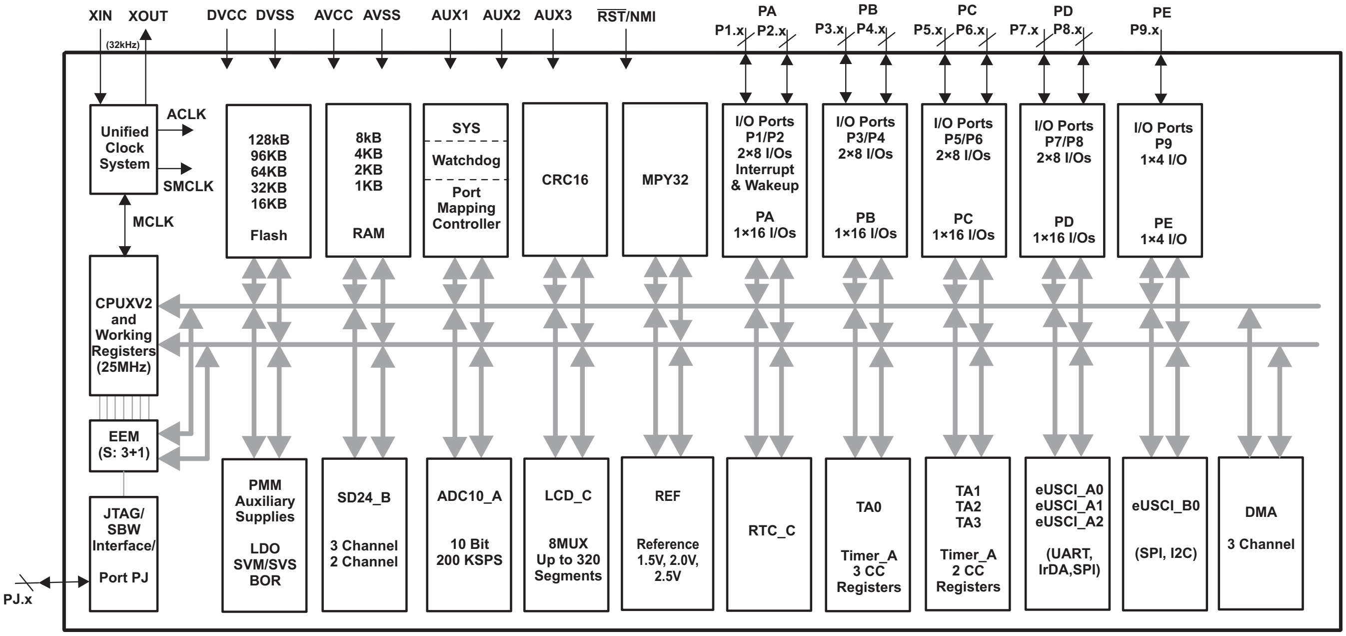


Figure 2. MSP430F6736 Functional Block Diagram

2.2 *SN65HVD3082E*

SN65HVD3082E is a group of half-duplex transceivers designed for RS-485 data-bus networks. Powered by a 5-V supply, these transceivers are fully compliant with the TIA/EIA-485-A standard. With controlled transition times, this device is suitable for transmitting data over long twisted-pair cables. This device is optimized for signaling rates up to 200 kbps and is designed to operate with a very low supply current, typically 0.3 mA, exclusive of the load. In the inactive shutdown mode, the supply current drops to a few nanoamps, making these devices ideal for power-sensitive applications.

2.3 *UA78L05*

This series of fixed-voltage integrated-circuit voltage regulators is designed for a wide range of applications, including on-card regulation to eliminate noise and distribution problems associated with single-point regulation. In addition, the applications can be used with power-pass elements to make high-current voltage regulators. One of these regulators can deliver up to 100 mA of output current. The internal limiting and thermal shutdown features of these regulators make them essentially immune to overload. When used as a replacement for a Zener diode-resistor combination, output impedance can effectively improve with a lower-bias current.

3 Block Diagram

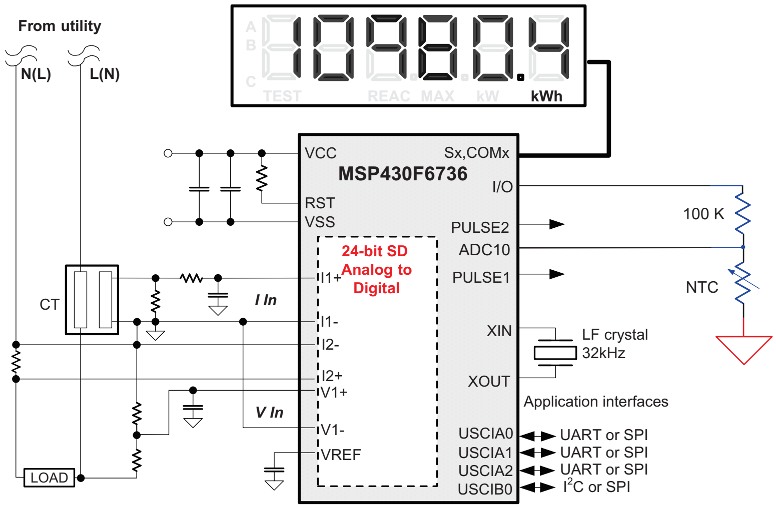


Figure 3. Block diagram for E-Meter RTC application using MSP430F6736

4 System Design Theory

The real-time clock (RTC) is the fundamental function for multi-toll controls in the smart meter. The RTC generates two outputs for the other functions of the smart meter:

1. The calendar—The calendar uses the format of year/month/day/hour/minute/second. The calendar must be non-volatile during power down and reset because the smart meter may work in very tough environments, but the electric energy bill must never be wrong.
2. The 1-second pulse—The 1-second pulse is a square pulse signal generated by the RTC chip once per second. This pulse is used for RTC calibration and certification.

Both the calendar and 1-second pulse are related to the multi-toll control, thus they have very strict requirements:

1. Accuracy—The RTC must be very accurate. In most specifications, the error rate under room temperature should be fewer than 5 ppm.
2. Temperature compensated—The crystal’s frequency may drift away when working temperatures rise or drop. The RTC must be able to compensate for the crystal's drift to remain accurate across the whole working range. The RTC error rate across the whole working temperature has different specifications in different countries. For example, in China, the limitation is 10 ppm.
3. Ultra-low power—The power consumption of the RTC is very critical. The RTC functions must be awake even during power failure. During power failure, the smart meter is powered by an embedded unchangeable battery that must be run for at least five years. In most countries, the power consumption of the RTC must be lower than 2 µA.

4.1 Crystal Frequency Temperature Compensation

All MCU-based smart-meter solutions use a 32-kHz low-frequency watch crystal as one of the clock's sources. The frequency output of the crystal varies considerably due to the drift in temperature. The RTC must compensate for this temperature drift for higher accuracy in time keeping from standard crystals. The typical temperature curve of a 32-KHz crystal is shown in Figure 4:

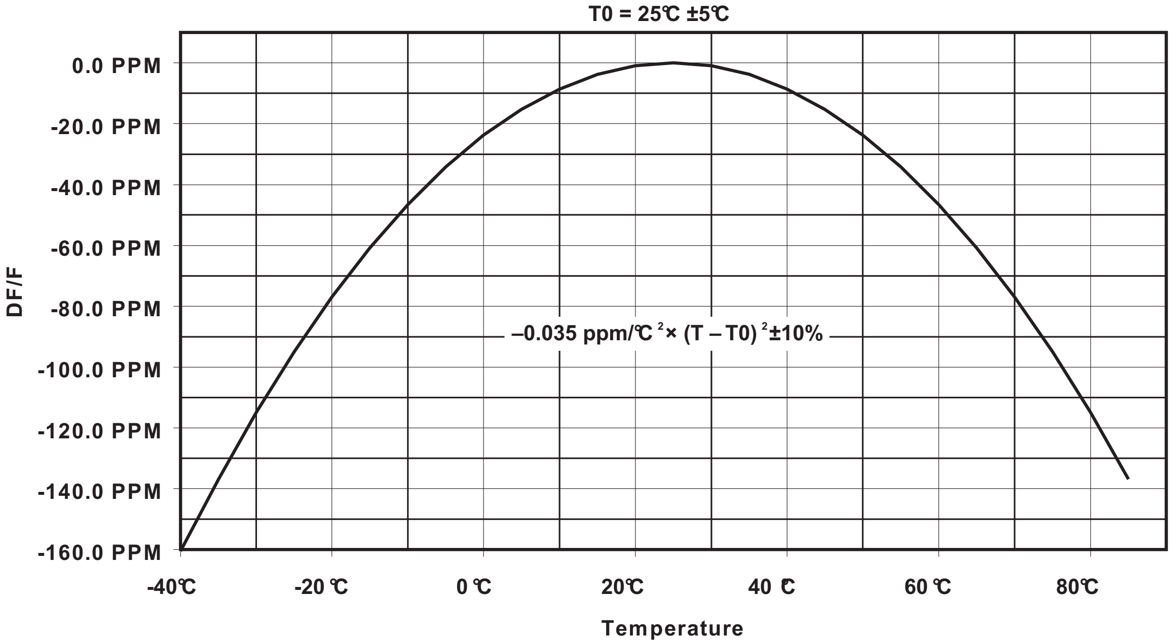


Figure 4. Crystal Temperature Curve

The above curve is very close to a parabola curve, so the frequency variation of a 32-KHz crystal can be predicted by the following formula:

$$E = K \times (T - T0) \times (T - T0) + B \quad (1)$$

Here, E is the frequency error of the crystal (which relates to three factors: K, T0, and B). T is the crystal's working temperature.

B is the frequency deviation of a crystal in room temperature. Each crystal’s frequency deviation is not the same, but each crystal’s frequency deviation is its inherent characteristic and will not change with time. The crystal’s deviation can be measured at room temperature (around 25°C) because the parabola curve is quite flat at the central point.

T0 and K are two factors to describe the parabola curve, denote the curve’s central point, and roll down speed, respectively. These two factors are decided by the production process of the crystal. Usually, T0 and K are almost the same among the same batch of crystals.

In some circumstances, the whole crystal's temperature curve will be divided into three or five segments within the temperature axis. On each of the segments is a parabola curve to represent the temperature feature of the crystal in this temperature range. The three or five parabola curves compose the whole picture of a crystal’s temperature feature, making it possible to better approach the crystal’s real characteristics.

Normally, the 32-KHz crystal vendors can provide such temperature curves of their crystals and the related parameters K and T0 to their end users. This process makes it possible to compensate crystal frequency error with software, without much effort on calibration.

4.2 Temperature Measurement

After getting the crystal temperature factors K and T0 from the crystal vendor and calibrating the crystal's deviation in room temperature, measure the working temperature for an overall frequency-error calculation.

MSP430F6736 integrated a 10-bit ADC, to which an on-chip temperature sensor is connected internally. Because the MSP430F6736 IC is very closed to 32-KHz crystal on an e-meter board, the temperature of the crystal can be treated identically to the one measured by the on-chip temperature sensor. Composing an on-chip ADC10 and an on-chip temperature sensor is the simplest way to measure the crystal's working temperature.

To use internal temperature sensor for temperature measurement, set the ADC10 on channel 10 and guarantee the sample period is greater than 30 µs.

One important limitation of MSP430F6736's internal temperature sensor is accuracy: its maximum error is 3°C, which results in up to a 13-ppm error on frequency calculations in an 85°C testing point. The MSP430F6736's internal temperature sensor is hard to be used in e-meter applications before being manually calibrated.

For better accuracy, use the external temperature sensor. A typical low-cost temperature sensor is the NTC resistor. The NTC resistor's resistance changes dramatically when it's working temperature changes. If we can measure the resistance of NTC, we can get its working temperature. Figure 5 shows the circuit to measure NTC resistance.

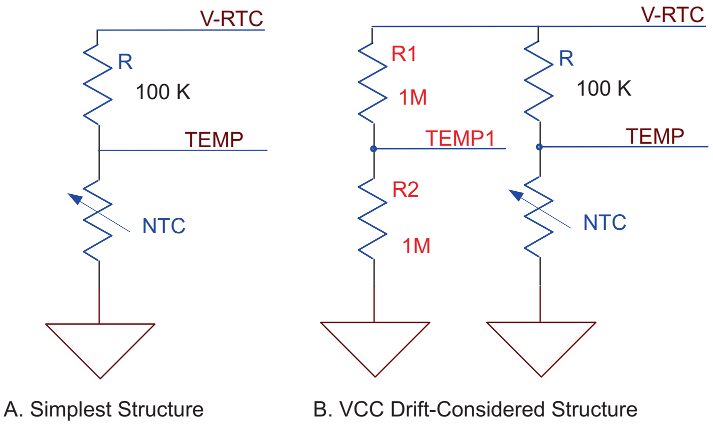


Figure 5. NTC Temperature Measurement Circuit

The simplest usage of NTC is as part A of Figure 5 shows. The V-RTC is the power source for the resistor ladder. This power source is supplied by MSP430F6736 GPIO and can be shut down to GND for power saving when temperature is not measured. TEMP is the tap where the voltage on NTC is fed out to ADC10. The resistor of NTC will be as follows:

$$R_{NTC} = \frac{V_{TEMP} \times R}{V_{V-RTC} - V_{TEMP}} \tag{2}$$

V-RTC is the power supply voltage for MCU. R is the resistance for R. If we can measure the voltage drop on NTC (V_{TEMP}) with ADC10, we can calculate the resistance of NTC.

In real e-meter applications, the power supply for the MCU V-RTC may drift because of working temperature or disturbance from a power grid. The calculated resistance of NTC may have errors, so we prefer to use the second structure to measure as part B of Figure 5 shows.

In this structure, a new branch resistor ladder is implemented, so the calculation on NTC resistance will be as follows:

$$R_{NTC} = \frac{V_{TEMP} \times R \times R_2}{V_{TEMP1} \times (R_1 + R_2) - V_{TEMP} \times R_2} \tag{3}$$

The NTC resistance calculation of structure B is irrelevant to power supply.

4.3 The Implementation of RTC_C Module

The RTC_C module allows users to compensate crystal errors that either result from crystal individual frequency offset or temperature influence. For crystal frequency offset, users must calibrate the crystal in room temperature and get the error between the crystal frequency and standard 32768 Hz. For temperature influence, users can calculate the crystal frequency error based on the crystal's temperature curve with the measured temperature. All errors are in PPM and need to be written into RTCOCAL and RTCTCMP respectively to compensate offset and temperature influence.

The RTC_C module has a dedicated clock source from the external 32-KHz crystal and has a dedicated power supply. The RTC_C module can work in stand-alone mode without taking any MCU MIPS, and the power consumption is typically only 0.34 µA in room temperature.

The RTC_C module also integrates calendar and alarm functions.

Figure 6 shows the RTC_C module implementation flow chart.

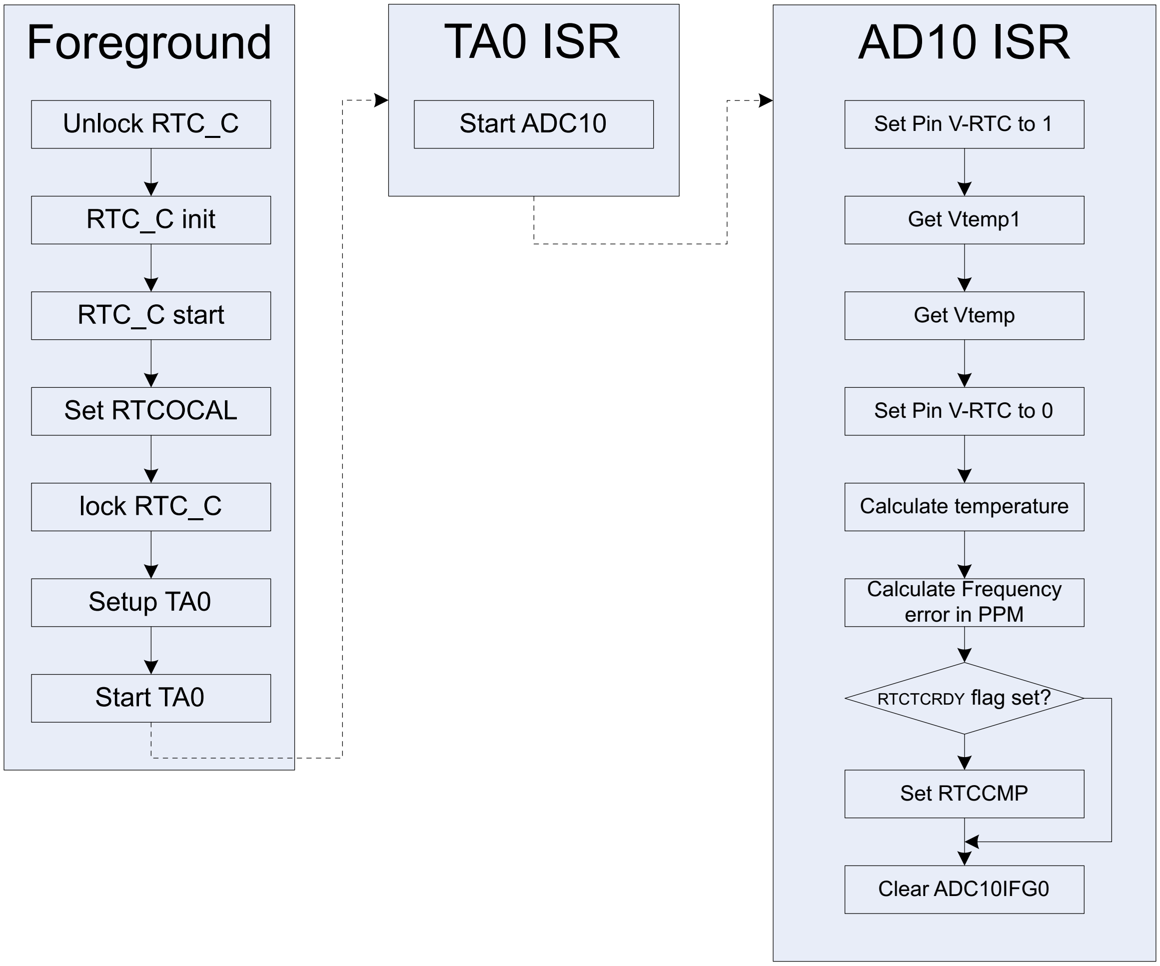


Figure 6. RTC_C Module Software Control Flow

The RTC_C module can also output second ticks (1-Hz clock) on the RTCCLK pin. However, because the frequency compensation in RTC_C module is in 60 µs per step, the second ticks output from the RTC_C module can only be accurate in a one-minute scale. For example, the accumulated error of 60 consecutive second ticks can be calibrated to 0, but the error of a single second tick will be up to 60 ppm.

4.4 Ultra-Low-Power Second Ticks Generation

In many applications, the error on second ticks must be measured solely or in 10-second scales. Here, we use software to fine tune the accuracy of every second tick.

MSP430F6736 has a very flexible clock system, and the integrated FLL plus many pre-scale dividers easily facilitate a 1-MHz SMCLK clock internally. Because the SMCLK is actually sourced from the external 32-KHz crystal through PLL, the error rate of the external crystal is the same as that of SMCLK. The frequency compensation to SMCLK can also be made with the same rate as the crystal.

Figure 7 shows how to use the 1-MHz clock and Timer_A to compensate frequency errors and generate second ticks.

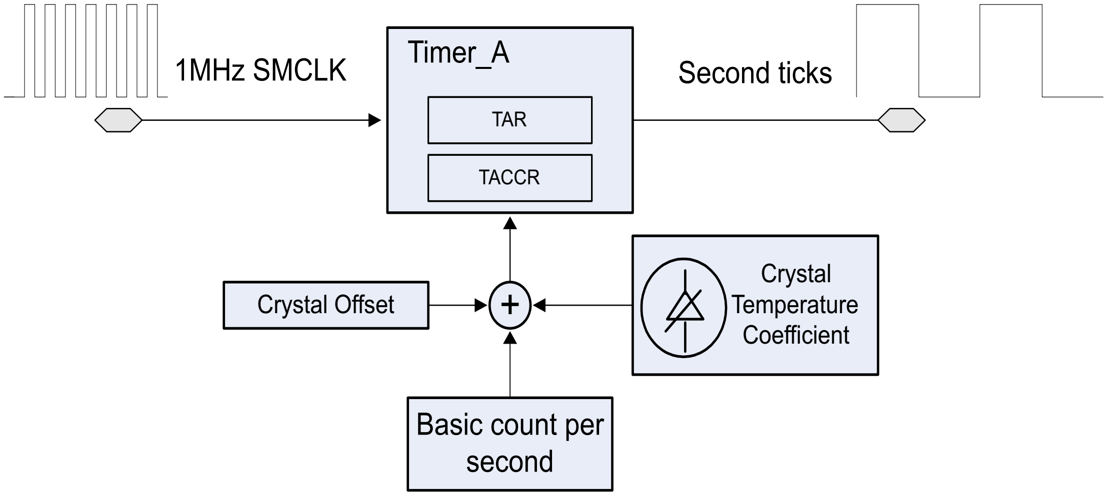


Figure 7. Frequency Compensation and Second Ticks Generation

In the frequency compensation stage, use the same process as with RTC_C:

1. Get working temperature through external NTC
2. Calculate the overall frequency error E caused by temperature and initial deviation based on crystal's temperature parabola curve Equation 1, in PPM
3. Subtract the frequency error E and get the exact SMCLK clock count per second.

Through Timer_A, the second ticks generation is actually a frequency divider. Because the clock source of Timer_A is the 1-MHz SMCLK, adding or subtracting 1 SMCLK in TACCR is equal to fine tuning the output of the second ticks frequency by 1 ppm.

The limitation of the above temperature-compensated second tick generation system is the power consumption. If the 1-MHz SMCLK keeps running for Timer_A, MSP430 has to run in LPM0 while sleeping, and the power consumption is typically 83 µA. However, in many applications (like e-meter), the whole system is powered by batteries if the main power source drops. The system requires RTC's power consumption to reduce to micro-ampere level.

Because high-speed clocks consume more power during the same time, one way to cut down power consumption is to compose different clocks—high speed clock and low speed clock—to fill the whole 1-second counting period.

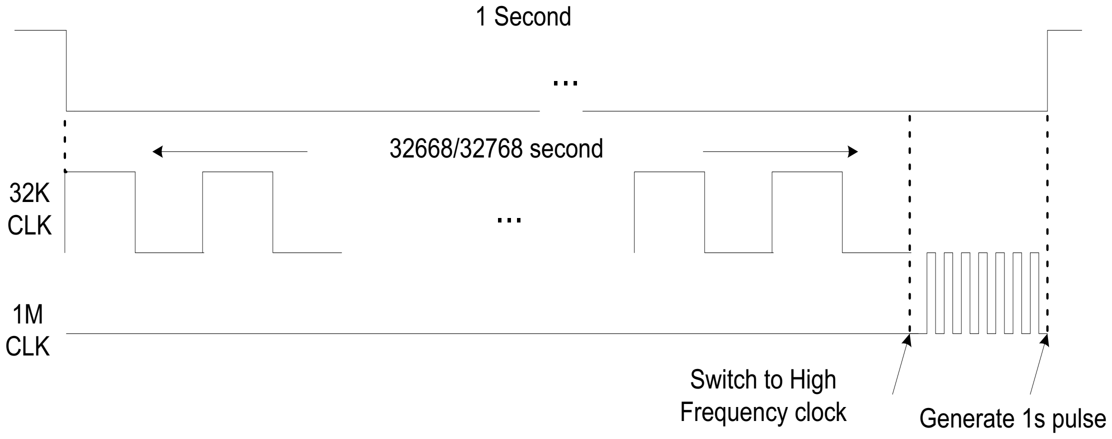


Figure 8. Fill 1-Second Counting Period with Different Clocks for ULPP

As Figure 8 shows, if we use a 32-KHz clock to count for 32766 / 32768 second and use another 1-MHz clock to count the last 100 / 32768 second and decide on the point when we generate second ticks, we can still fine tune the second tick's accuracy in 1-ppm steps while reducing the overall power consumption dramatically to the following: $I_E = I_{LPM3}\frac{32668}{32768} + I_{LPM0}\frac{100}{32768}$

Where I_E is the average power consumption, I_{LPM0} is the power consumption in LPM0 mode, and I_{LPM3} is the power consumption in LPM3 mode. In the MSP430F6736 data sheet, the power consumption for LPM0 mode is 83 µA, and the power consumption for LPM3 mode is 2.5 µA. The average power consumption for software RTC and second ticks generation is 2.74 µA.

In this application, two Timer_A modules are used to implement clock switching and second ticks generation. Figure 9 shows the time sequence of two TA modules.

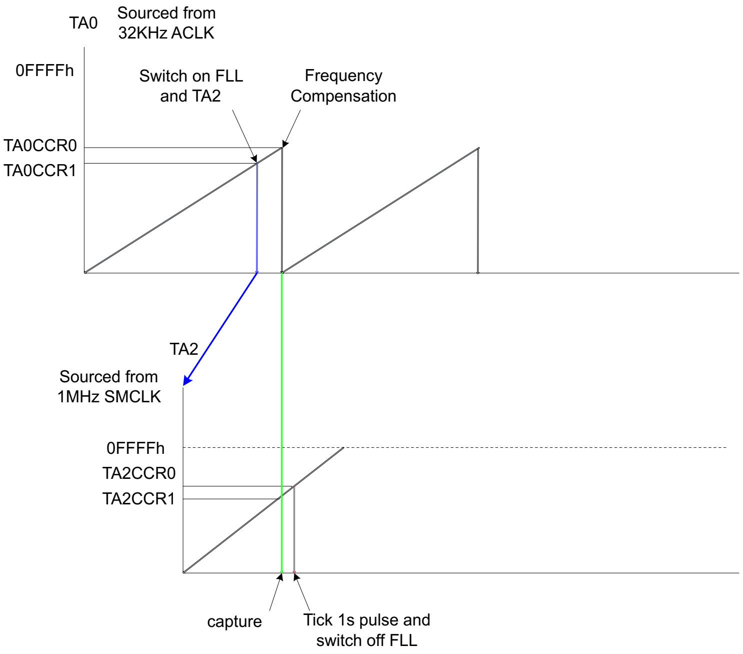


Figure 9. Ultra-Low-Power Second Ticks Generation

TA2 sources from the 1-MHz SMCLK. TA2 is shut down until TA0 ISR wakes it up. TA0 sources from the 32-KHz ACLK. TA0 is always on, and it runs in up and compare-out modes. TACCR0 stores the value when TA2 is switched on to fine tune the second ticks. Because TA2 sources from SMCLK, switch on FLL for several ACLK before switching on TA2, so that enough time exists to stabilize SMCLK before TA2 is used for SMCLK counting. TACCR1 stores the value when FLL will be switched on.

The TA0 and TA2 running sequence will be as follows:

1. At the beginning, TA0 is on and MCU runs in LPM3 mode.
2. When TA0R reaches TA0CCR1, FLL is switched on (MCU switches to LPM0) and TA2 is started in TA0 ISR. TA2 is initiated in capture mode and TA2CCR1 is set to always capture on ACLK.
3. Several ACLK later when TA0CCR1 is reached and TA0 ISR is triggered, frequency errors accumulate caused by temperature change and offset deviation. These accumulations are used to calculate when to send out second ticks by summing frequency error with TA2CCR1. Finally, the summary to TA2CCR0 is written, and TA2 is set to compare-out mode to generate second ticks.
4. In the last step after generating second ticks, switch off TA2 and FLL and go back to LPM3 in TA2 ISR.

NOTE: We used TA2 in capture mode and recorded the exact TA2R value to TA2CCR1 instead of directly reading the TA2R value. By doing this, we can avoid the error caused by TA2 ISR interrupting the latency difference.

Figure 10 is the software flow chart for ULPP second ticks generation.

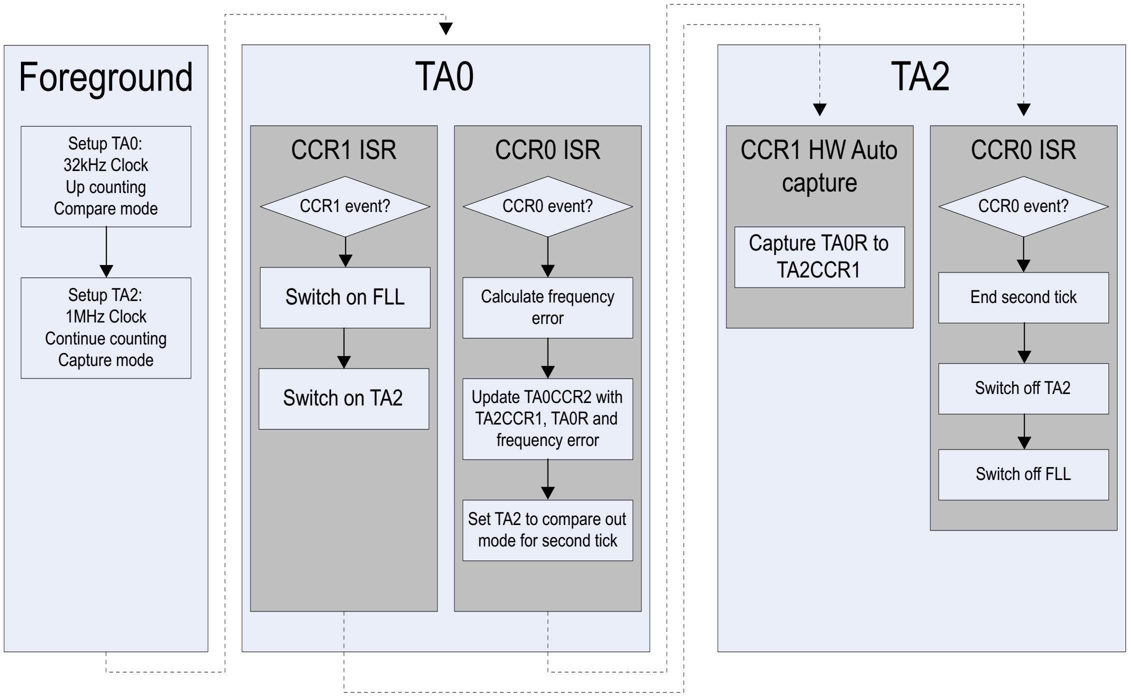


Figure 10. ULP Second Tick Software Flow

5 Getting Started Hardware

To debug the system, the necessary test points are designed on J16 as shown in Figure 11. The testing wire must connect to these points to connect with the debugging tools. To test the frequency errors, use the frequency equipment that has 1-ppm accuracy, and connect the wire from J6 to the frequency equipment. To test the influence by temperature, use a thermostat that can adjust the temperature from –40℃ to 80℃.

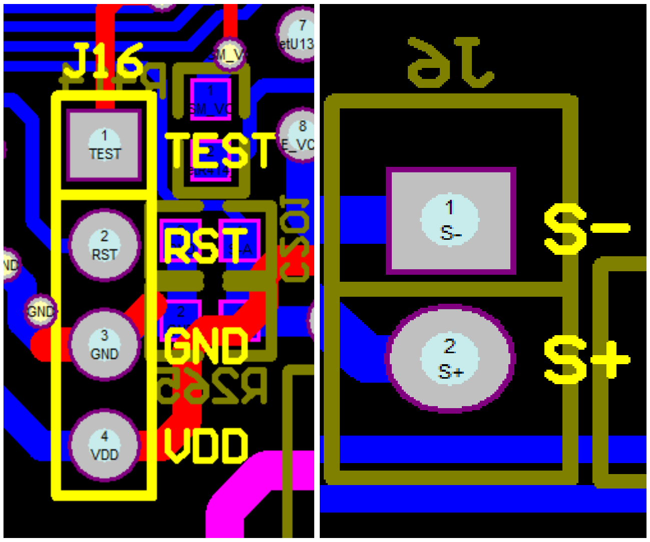


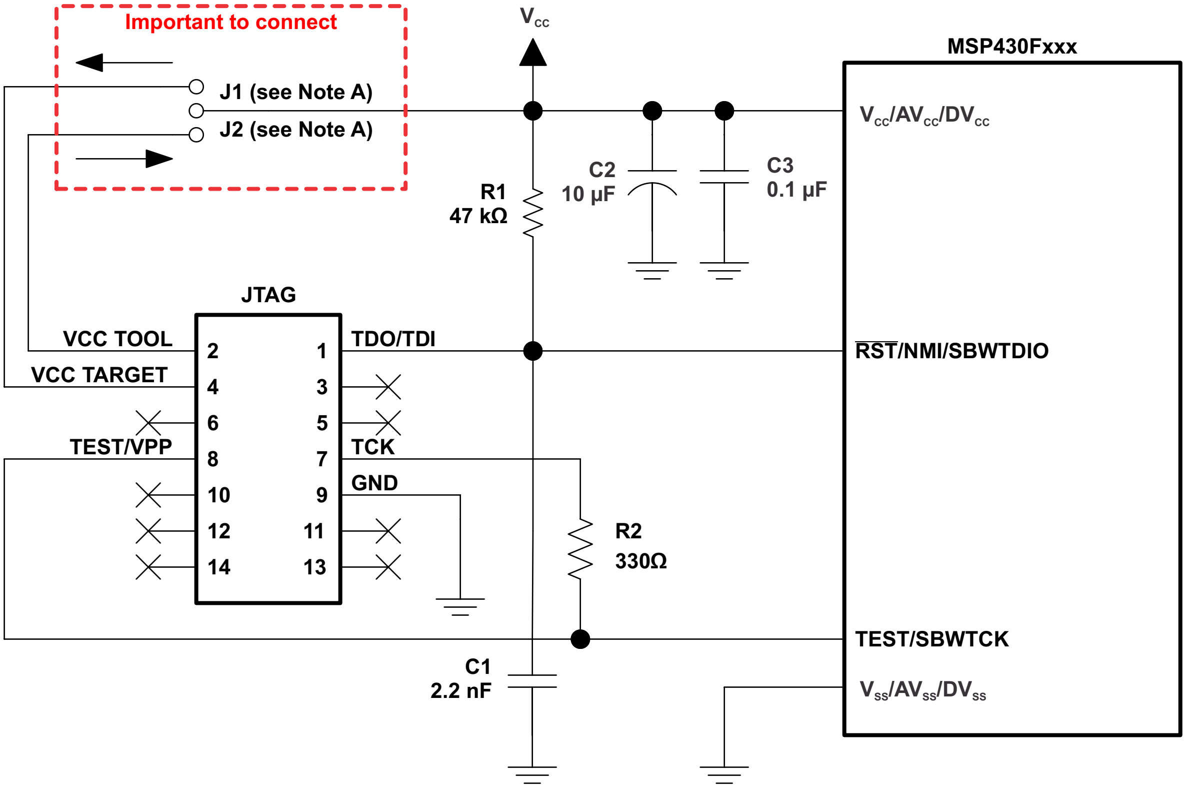
Figure 11. MSP430 Spy-Bi-Wire Interface and Second Pulse interface

5.1 MSP430 USB Debugging Interface

The MSP430-FET430UIF, which is shown in Figure 12, debugs the firmware on the MCU.

Figure 12. MSP430-FET430UIF

To debug the MCU software, connect only four points on the board to the debugger: VCC, GND, RST, and TEST. The connection should follow Figure 13.



A If a local target power supply is used, make connection J1. If power from the debug or programming adapter is used, make connection J2.

Figure 13. Spy-Bi-Wire Connection

6 Getting Started Firmware

This firmware mainly includes the folder ”emeter-rtc”, which includes emeter-rtc-inter.c, emeter-rtc.c, emeter-rtc-lib.c, and more. **For convenience in further development, the firmware provides the APIs that realize functions of the RTC calibration and RTC parameters' reading**. This firmware will occupy some hardware resources as shown in Table 1:

Table 1. Resources Used by Firmware

RESOURCE	RTC FIRMWARE
FLASH	3220 bytes
RAM	78 bytes
TA0	Y
TA1	Y
ADC10	Y
SMCLK	Require 4 MHz
I/O	TA1.0 PWM second-pulse output
REF	ADC using REF 2.5 V

If we need to use this firmware, we only need include the “emeter-rtc-inter.h” file and add the “emeter-rtc\emeter-rtc-6736\Debug\Exe\emeter-rtc-6736.r43” file to the project.

6.1 Firmware API

This firmware provides two API: one is for getting, and the other is for setting.

The following function sets all parameters that will be used by the firmware:

void set_rtc_parameter(int address, int32_t value)

The following function gets all parameters from the firmware inside:

int32_t get_rtc_parameter(int address, void *ptr)

Below are the parameters to get or set.

- RTC_CRYSTAL_BASE_OFFSET

  Description: The fixed bias of the oscillator at room temperature. Reads and writes.

  Unit: ppm.

  Note: ppm > 0 means faster than the standard, and ppm < 0 means slower than the standard.

- RTC_CURRENT_TIME

  Description: Gets and sets current time. Reads and writes. The time is structured as follows:

  struct rtc_interface {

uint8_t year;	value: 0–100
uint8_t month;	value: 1–12
uint8_t week;	value: 0–6, Sunday = 0
uint8_t day;	value: 1–28, 30, 31
uint8_t hour;	value: 0–23
uint8_t minute;	value: 0–59
uint8_t second;	value: 0–59

  };

  Note: The void is called set_rtc_parameter(int address, int32_t value) or int32_t get_rtc_parameter(int address, void *ptr) for RTC_CURRENT_TIME, which needs to pass the point of the struct rtc_interface variable.

- RTC_CURRENT_MODE

  Description: RTC current working mode. Reads and writes.

  Value: Includes two modes:

  enum RTC_STATUS {

  RTC_LOW_POWER_STATUS = 0, low-power mode RTC_OPEN_STATUS, normal power mode

  };

  Note: In low-power mode, this firmware will not output a second pulse; it will only compensate for the error influenced by the temperature.

- RTC_CURRENT_TEMP

  Description: Gets current temperature. Only reads.

  Unit: 0.25°C

- RTC_ERROR_STATUS

  Description: Reports if RTC has something wrong. Only reads.

  Value: 1 = error, 0 = normal

- RTC_ADC_BATTERY_RAW

  Description: Gets battery ADC value using 2.5-V REF. Only reads.

Value: 1 = error, 0 = normal

- RTC_NTC_POWER_ON_CB

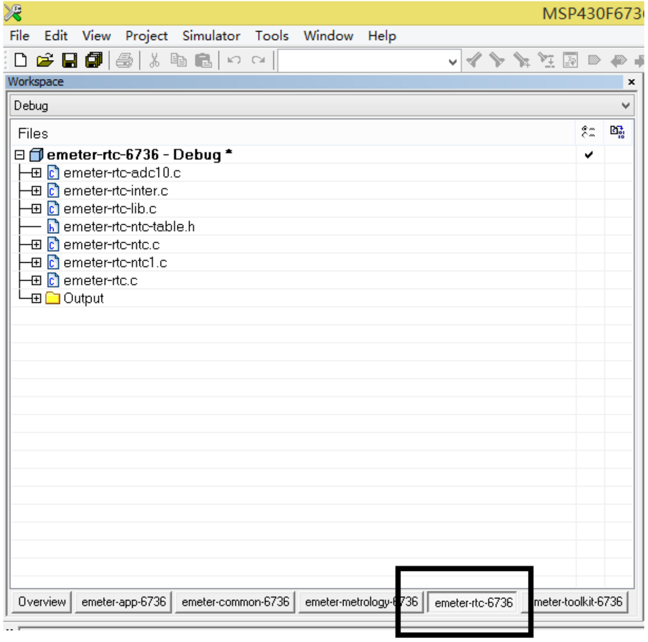
  Description: Callback function that lets the power I/O pin high.
- RTC_NTC_POWER_OFF_CB

  Description: Callback function that lets the power I/O pin low. Only writes.

- RTC_CRYSTAL_COEFF0
- RTC_CRYSTAL_COEFF1
- RTC_CRYSTAL_COEFF2
- RTC_CRYSTAL_COEFF3
- RTC_CRYSTAL_COEFF4
- RTC_CRYSTAL_COEFF5

  Description: Sets crystal curve coefficient according to the crystal curve parameter.

6.2 Firmware Use in IAR Project



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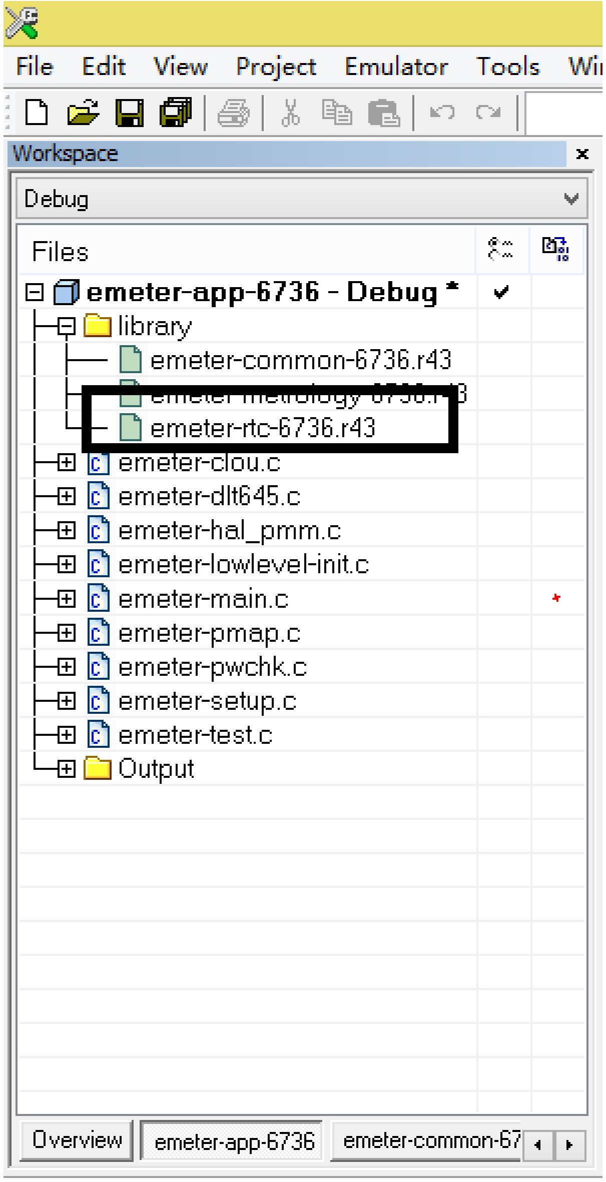
- emeter-rtc-adc10.c
- emeter-rtc-inter.c
- emeter-rtc-lib.c
- emeter-rtc-ntc-table.h
- emeter-rtc-ntc.c
- emeter-rtc-ntc1.c
- emeter-rtc.c
- Output

Figure 14. IAR Project File: E-Meter-RTC-6736



emeter-app-6736 - Debug *
- library
  - emeter-common-6736.r43
  - emeter-metrology-6736.r43
  - emeter-rtc-6736.r43
- emeter-clou.c
- emeter-dlt645.c
- emeter-hal_pmm.c
- emeter-lowlevel-init.c
- emeter-main.c
- emeter-pmap.c
- emeter-pwchk.c
- emeter-setup.c
- emeter-test.c
- Output

Figure 15. IAR Project File: E-Meter-APP-6736

7 Test Data

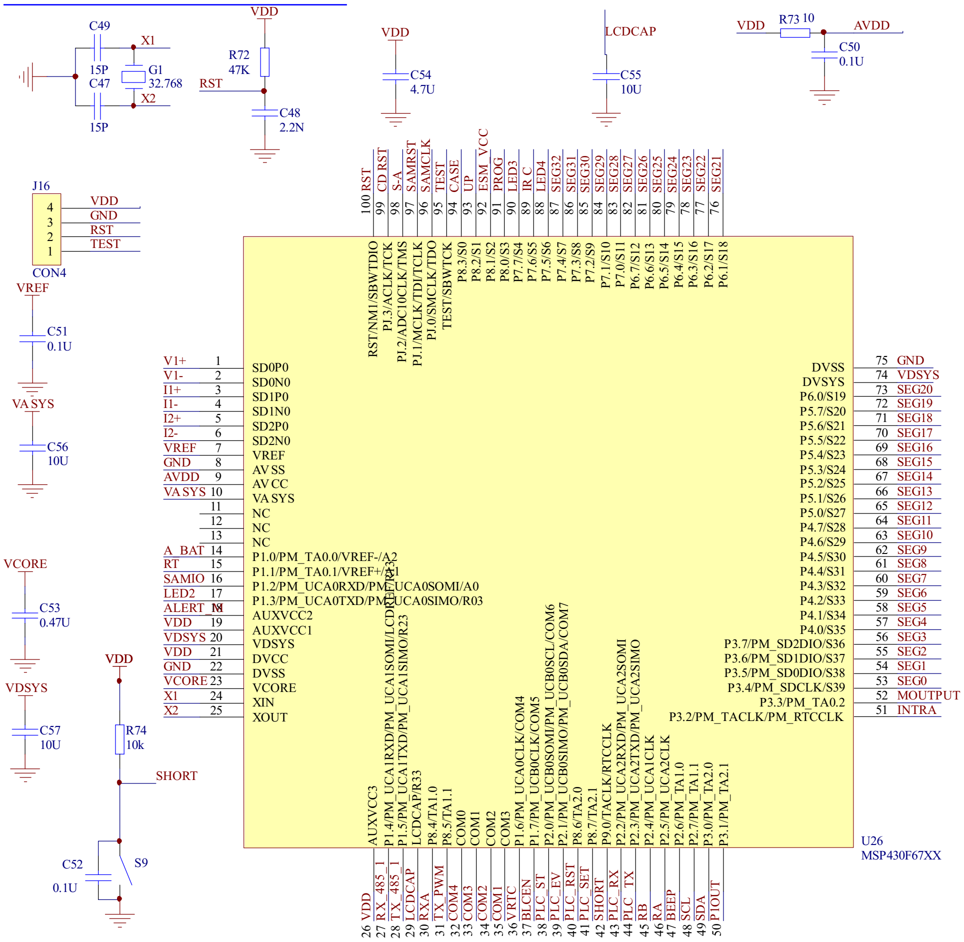
Table 2. Test Data When Using Temperature Compensated

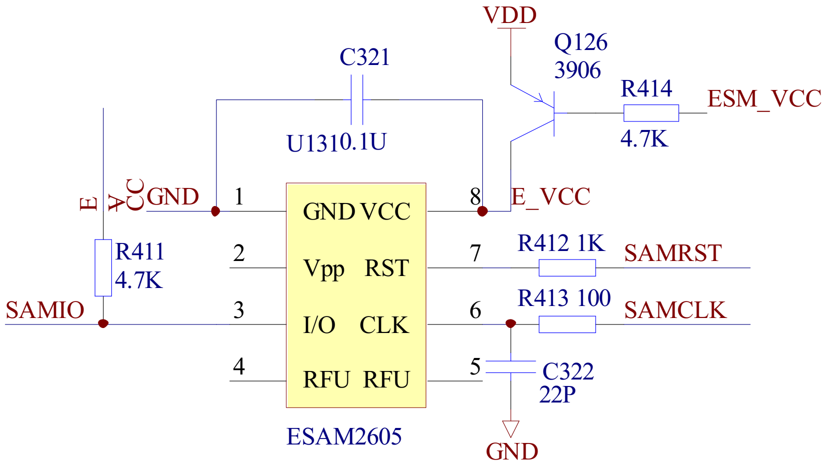
IDEAL TEMP °C	IDEAFREQ ERR (ppm)	GAP FREQ (ppm)	IDEAL FREQ (mHZ)	MEAS FREQ (mHz)	NO CALIBRATION ERR	CALIBRATION ERR
73	83.75	91.7	1000	999.9083	–7.95	–6.95
63	53.6	58	1000	999.942	–4.4	–3.4
53	30.15	32.7	1000	999.9673	–2.55	–1.55
43	13.4	14.7	1000	999.9853	–1.3	–0.3
33	3.35	4	1000	999.996	–0.65	0.35
23	0	1	1000	999.999	–1	0
13	3.35	6	1000	999.994	–2.65	–1.65
3	13.4	17.7	1000	999.9823	–4.3	–3.3
–7	30.15	34.7	1000	999.9653	–4.55	–3.55
–17	53.6	58	1000	999.942	–4.4	–3.4
–27	83.75	88.3	1000	999.9117	–4.55	–3.55
–37	120.6	123.3	1000	999.8767	–2.7	–1.7

8 Design Files

8.1 Schematics

To download the schematics for each board, see the design files at http://www.ti.com/tool/TIDM-TEMPCOMPENSATED-RTC.

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Q126
3906
R414
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U131
0.1U
4.7K
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GND
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E_VCC
R411
4.7K
2
Vpp RST
7
R412 1K
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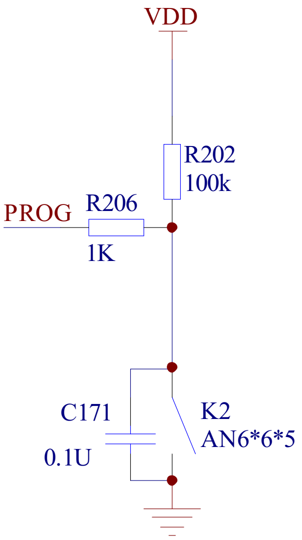
22P
ESAM2605
GND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PROG
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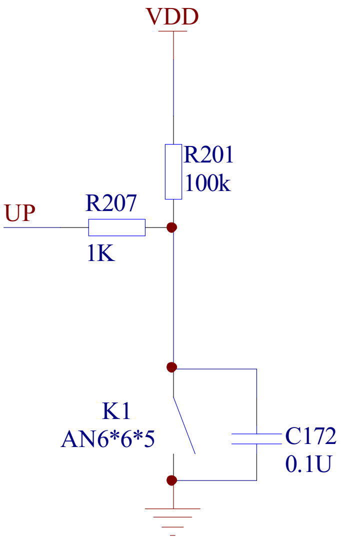
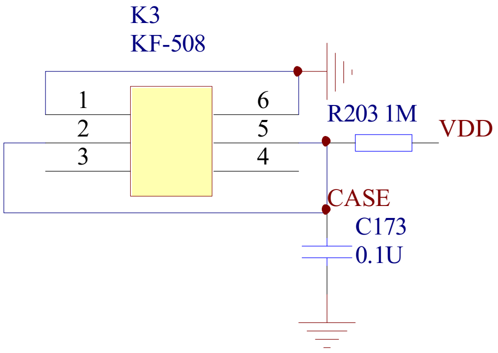
1K
C171
0.1U
K2
AN6*6*5


VDD
R201
100k
UP
R207
1K
K1
AN6*6*5
C172
0.1U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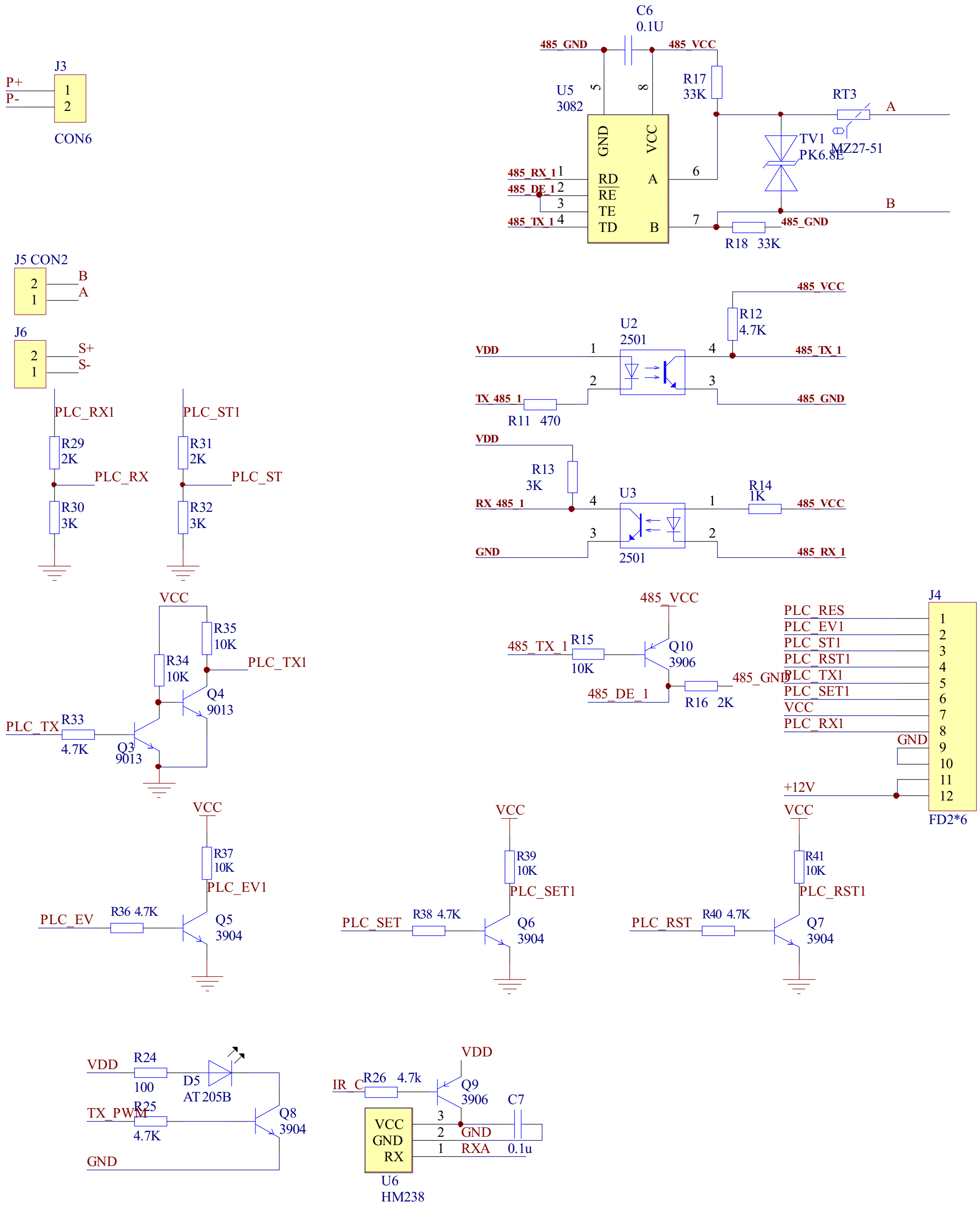
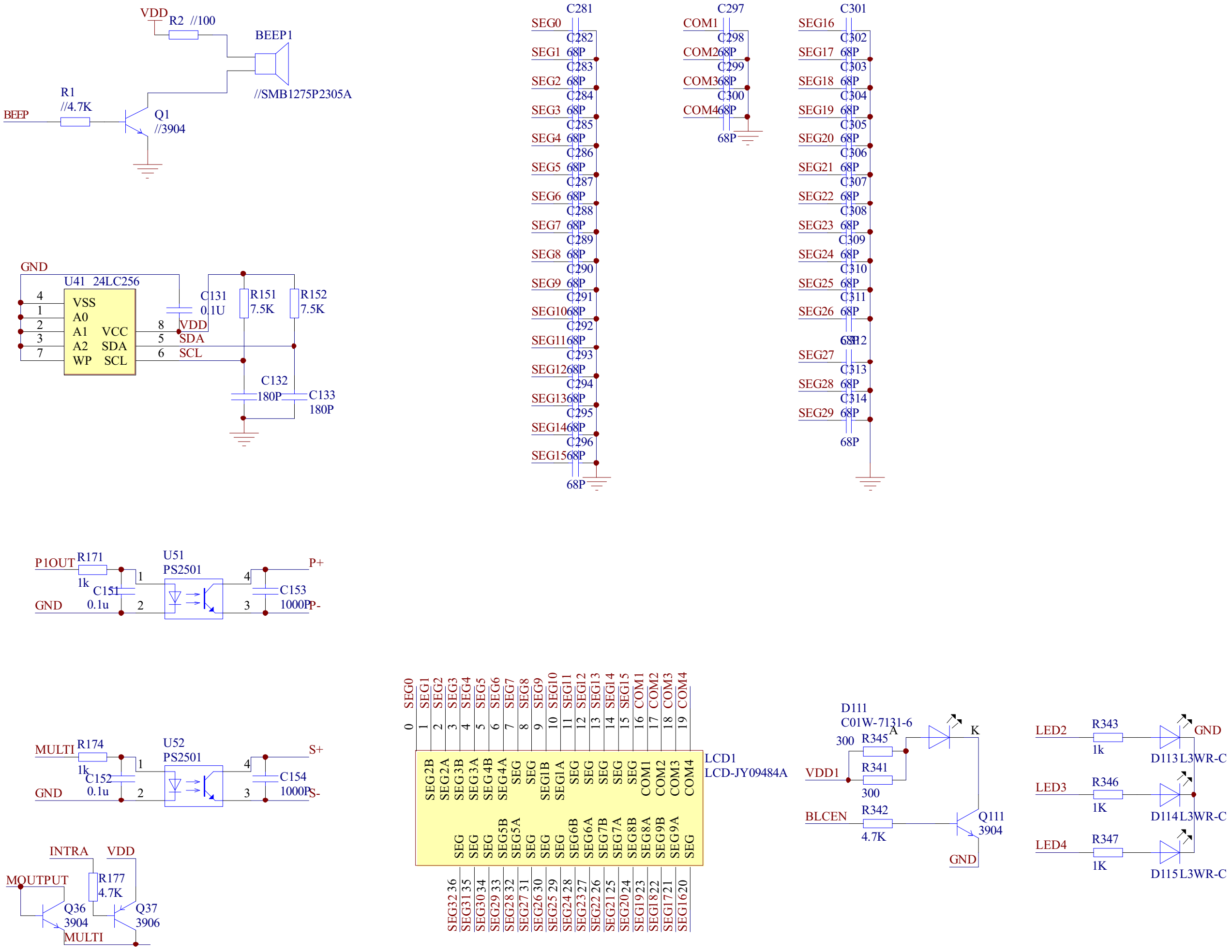
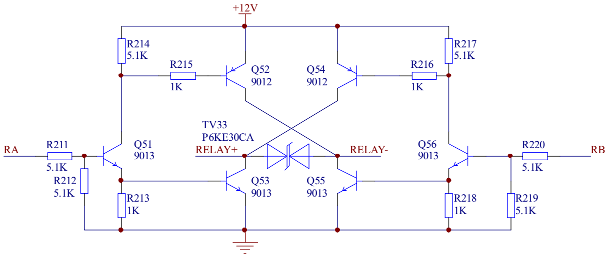
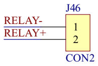
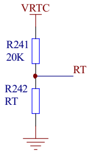
KF-508
1
2
3
6
5
4
R203 1M
VDD
CASE
C173
0.1U

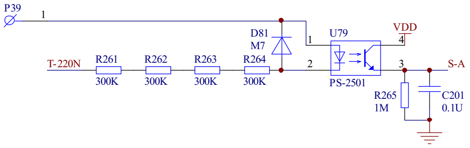

J3
P+
P-
1
2
CON6
C6
0.1U
485_GND
485_VCC
U5
3082
5
8
R17
33K
RT3
A
GND
VCC
TV1
PK6.8E
MZ27-51
485_RX_1
485_DE_1
485_TX_1
1
2
3
4
RD
RE
TE
TD
A
B
6
7
B
485_GND
R18 33K
J5 CON2
2
1
B
A
J6
2
1
S+
S-
485_VCC
R12
4.7K
U2
2501
VDD
1
4
485_TX_1
2
3
TX_485_1
R11 470
485_GND
VDD
R13
3K
U3
R14
1K
RX_485_1
4
1
485_VCC
3
2
GND
2501
485_RX_1
PLC_RX1
R29
2K
PLC_RX
R30
3K
PLC_ST1
R31
2K
PLC_ST
R32
3K
VCC
R35
10K
PLC_TX1
R34
10K
Q4
9013
PLC_TX
R33
4.7K
Q3
9013
485_VCC
485_TX_1
R15
10K
Q10
3906
485_GND
485_DE_1
R16 2K
J4
PLC_RES
PLC_EV1
PLC_ST1
PLC_RST1
PLC_TX1
PLC_SET1
VCC
PLC_RX1
GND
+12V
1
2
3
4
5
6
7
8
9
10
11
12
FD2*6
VCC
R37
10K
PLC_EV1
PLC_EV
R36 4.7K
Q5
3904
VCC
R39
10K
PLC_SET1
PLC_SET
R38 4.7K
Q6
3904
VCC
R41
10K
PLC_RST1
PLC_RST
R40 4.7K
Q7
3904
VDD
R24
100
D5
AT205B
TX_PWM
R25
4.7K
Q8
3904
GND
VDD
IR_C
R26 4.7k
Q9
3906
C7
VCC
GND
RX
3
2
1
GND
RXA
0.1u
U6
HM238

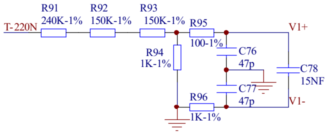

VDD
R2 //100
BEEP1
//SMB1275P2305A
R1
//4.7K
BEEP
Q1
//3904
GND
U41 24LC256
VSS
A0
A1
A2
WP
VCC
SDA
SCL
VDD
SDA
SCL
C131 0.1U
R151 7.5K
R152 7.5K
C132 180P
C133 180P
C281 … C296 68P
SEG0 … SEG15
C297 … C300 68P
COM1 COM2 COM3 COM4
C301 … C314 68P
SEG16 … SEG29
P1OUT
R171 1k
C151 0.1u
U51 PS2501
C153 1000P
P+
P-
MULTI
R174 1k
C152 0.1u
U52 PS2501
C154 1000P
S+
S-
INTRA
VDD
MOUTPUT
R177 4.7K
Q36 3904
Q37 3906
MULTI
LCD1
LCD-JY09484A
SEG2B SEG2A SEG3B SEG3A SEG4B SEG4A SEG SEG SEG1B SEG1A SEG SEG SEG SEG COM1 COM2 COM3 COM4
SEG SEG SEG SEG5B SEG5A SEG SEG SEG SEG6B SEG6A SEG7B SEG7A SEG8B SEG9B SEG9A SEG
D111
C01W-7131-6
A
K
R345 300
R341 300
VDD1
BLCEN
R342 4.7K
Q111 3904
GND
LED2
R343 1k
D113 L3WR-C
LED3
R346 1K
D114 L3WR-C
LED4
R347 1K
D115 L3WR-C
GND

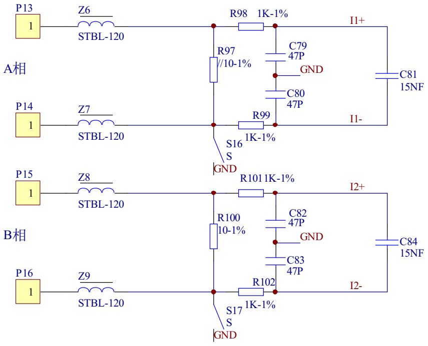

+12V
R214
5.1K
R215
1K
Q52
9012
Q54
9012
R216
1K
R217
5.1K
TV33
P6KE30CA
RELAY+
RELAY-
RA
R211
5.1K
R212
5.1K
Q51
9013
Q56
9013
R220
5.1K
RB
R213
1K
Q53
9013
Q55
9013
R218
1K
R219
5.1K

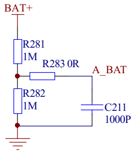

J46
RELAY-
RELAY+
1
2
CON2

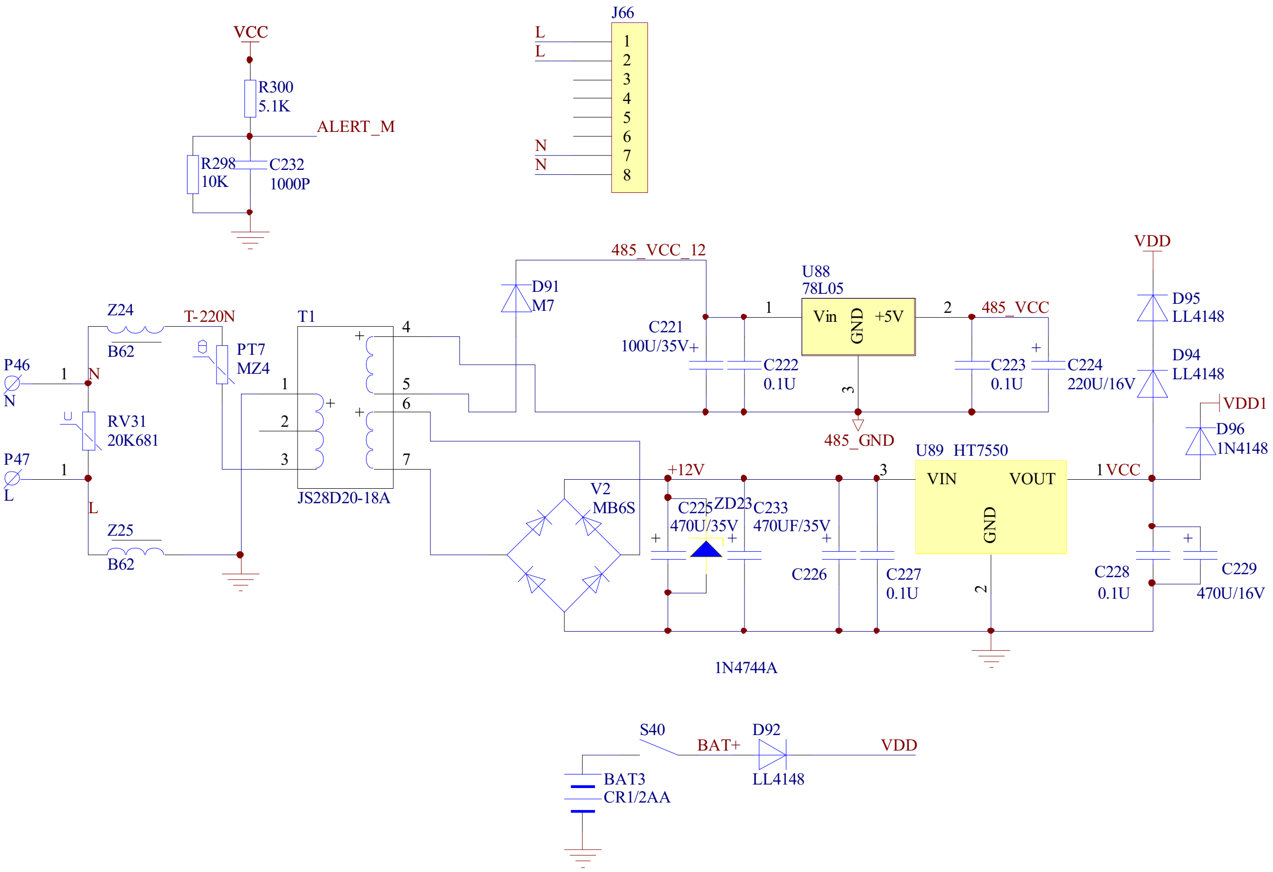

VRTC
R241
20K
RT
R242
RT


P39
1
D81
M7
U79
VDD
4
1
2
3
S-A
T-220N
R261
300K
R262
300K
R263
300K
R264
300K
PS-2501
R265
1M
C201
0.1U


R91
240K-1%
R92
150K-1%
R93
150K-1%
T-220N
R95
100-1%
V1+
R94
1K-1%
C76
47p
C78
15NF
C77
47p
R96
1K-1%
V1-


P13
1
Z6
STBL-120
R98
1K-1%
I1+
A相
R97
10-1%
C79
47P
GND
C81
15NF
C80
47P
P14
1
Z7
STBL-120
R99
1K-1%
I1-
S16
S
GND
P15
1
Z8
STBL-120
R101
1K-1%
I2+
B相
R100
10-1%
C82
47P
GND
C84
15NF
C83
47P
P16
1
Z9
STBL-120
R102
1K-1%
I2-
S17
S
GND


BAT+
R281
1M
R283 0R
A_BAT
R282
1M
C211
1000P



8.2 Bill of Materials

To download the bill of materials (BOM), see the design files at http://www.ti.com/tool/TIDM-TEMPCOMPENSATED-RTC.

Table 3. BOM

DESCRIPTION	VALUE	DESIGNATOR	PCS/UNIT	FOOTPRINT	MANUFACTURER
SMD, Capacitor, ±20%	0.1 µF	C6, C7, C50, C51, C52, C131, C151, C152, C171, C172, C173, C201, C222, C223, C227, C228, C321	17	603	Yageo
SMD, Capacitor, ±20%	0.47 µF	C53	1	603	Yageo
SMD, Capacitor, ±20%	2.2 nF	C48	1	603	Yageo
SMD, Capacitor, ±20%	4.7 µF	C54	1	603	Yageo
SMD, Capacitor, ±20%	10 µF	C55, C56, C57	3	805	Yageo
SMD, Capacitor, ±20%	1000 pF	C153, C154, C211, C232	4	603	Yageo
SMD, Capacitor, ±10%	180 pF	C132, C133	2	603	Yageo
SMD, Capacitor, ±10%	15 nF	C78, C81, C84	3	603	Yageo
SMD, Capacitor, ±10%	15 pF	C47, C49	2	603	Yageo

Table 3. BOM (continued)

DESCRIPTION	VALUE	DESIGNATOR	PCS/UNIT	FOOTPRINT	MANUFACTURER
SMD, Capacitor, ±10%	22 pF	C322	1	603	Yageo
SMD, Capacitor, ±10%	47 pF	C76, C77, C79, C80, C82, C83	6	603	Yageo
SMD, Capacitor, ±10%	68 pF	C281-C314	34	603	Yageo
SMD, Resistor, ±5%	O Ω	R283	1	603	Yageo
SMD, Resistor, ±5%	10 k	R15, R34, R35, R37, R39, R41, R74, R298	8	603	Yageo
SMD, Resistor, ±1%	1 k	R94, R96, R98, R99, R101, R102	6	603	Yageo
SMD, Resistor, ±5%	1 k	R14, R171, R174, R206, R207, R213, R215, R216, R218, R343, R346, R347, R412	13	603	Yageo
SMD, Resistor, ±5%	2 k	R16, R29, R31	3	603	Yageo
SMD, Resistor, ±5%	20 k	R241	1	603	Yageo
SMD, Resistor, ±5%	3 k	R13, R30, R32	3	603	Yageo
SMD, Resistor, ±5%	33 k	R17, R18	2	603	Yageo
SMD, Resistor, ±5%	300	R341, R345	2	603	Yageo
SMD, Resistor, ±5%	100 k	R201, R202	2	603	Yageo
SMD, Resistor, ±1%	100	R95	1	603	Yageo
SMD, Resistor, ±5%	100	R24, R413	2	603	Yageo
SMD, Resistor, ±1%	470	R11	1	603	Yageo
SMD, Resistor, ±5%	4.7 k	R12, R25, R26, R33, R36, R38, R40, R177, R342, R411, R414	11	603	Yageo
SMD, Resistor, ±5%	47 k	R72	1	603	Yageo
SMD, Resistor, ±5%	5.1 k	R211, R212, R214, R217, R219, R220, R300	7	603	Yageo
SMD, Resistor, ±1%	10	R100	1	603	Yageo
SMD, Resistor, ±5%	10	R73	1	603	Yageo
SMD, Resistor, ±5%	7.5 k	R151, R152	2	603	Yageo
SMD, Resistor, ±5%	1 M	R203, R265, R281, R282	4	603	Yageo
SMD, Resistor, ±5%	300 k	R261, R262, R263, R264	4	805	Yageo
SMD, Resistor, ±1%	150 k	R92, R93	2	1206	Yageo
SMD, Resistor, ±1%	240 k	R91	1	1206	Yageo
SMD, Diode	IN4148	D92, D94, D95, D96	4	IN4148-SMT	
SMD, MCU	MSP430F6736	U26	1	TQFP100-0.26	Texas Instruments
SMD, RS485	SN65HVD3082E	U5	1	SOIC8	Texas Instruments
SMD, EEPROM	24LC256B-I/SN	U41	1	SOIC8	
SMD, Transistors,NPN	3904	Q3, Q4, Q5, Q6, Q7, Q8, Q36, Q51, Q53, Q55, Q56, Q111,	12	3904_3906	NXP MMBT3904 MMBT3906
SMD, Transistors,PNP	3906	Q9, Q10, Q37, Q52, Q54, Q126	6	3904_3906	NXP MMBT3904 MMBT3906
SMD, LDO	78L05	U88	1	SOT-89	Texas Instruments

Table 3. BOM (continued)

DESCRIPTION	VALUE	DESIGNATOR	PCS/UNIT	FOOTPRINT	MANUFACTURER
SMD, LDO	HT7550	U89	1	SOT-89	HT
SMD, Rectifier Diode	M7	D81, D91	2	IN5817-SMT	Changjiang
SMD, Rectifier Bridge	MB6S	V2	1	MBS-1	Changjiang
SMD, NTC	RT-10 k	R242	1	805	Exsense
SMD, Bead	STBL-120	Z6, Z7, Z8, Z9	4	805	Yageo
Through-hole, LED	RED LED-Φ5	D113, D114, D115	3	LED	Changjiang
Through-hole, Crystal,12.5p–5ppm	32.768kHz VT200	G1	1	G-32.768	SEIKO
Through-hole, LCD	LCD-JY09484	LCD1	1	LCD-JY09484A	HEBEI JIYA
Through-hole, Voltage Transformer	JS28D20-18A	T1	1	TRANS-TD28-18-3	QINGZHOU JINSHUN
Through-hole, Back Light Panel	C01W-7131-6	D111	1	BG-ST-7131	SHENZHEN SAITE
Through-hole, lithium battery	ER14250AH	BAT3	1	B-CR1/2AA	YIWEI
Through-hole, Button	6*6*4.3	K1, K2	2	RESET	Zhongcheng
Through-hole, Micro-Switch	KF-508	K3	1	KFT-5.8	Zhongcheng
Through-hole, ESAM	ESAM2605	U131	1	DIP-8	CSG
Through-hole, Electrolytic Capacitor	100 U / 35 V	C221	1	D-D-F 6.3*0.5*2.50	Yageo
Through-hole, Electrolytic Capacitor	220 U / 16 V	C224	1	D*D*F 6.3*0.5*2.5	Yageo
Through-hole, Electrolytic Capacitor	470 U / 16 V	C229	1	D*D*F 8*0.6*3.5	Yageo
Through-hole, Electrolytic Capacitor	1000 U / 35 V	C225	1	D*D*F 12.5*0.6*5.0	Yageo
Through-hole, Zener diode	1N4744A	ZD23	1	DO41-UP	Changjiang
Through-hole, Piezoresistor	20K681	RV31	1	RV20K681	FNR
Through-hole, Optocoupler	PC817C	U2, U3, U51, U52, U79	5	DIP-4	Toshiba
Through-hole, Bead	B62	Z24, Z25	2	B62A	Yageo
Through-hole, Thermistor	MZ4-250	PT7	1	PTC-120/120-35MA	Yageo
Through-hole, Thermistor	MZ6-51R	RT3	1	PTC-120/120-35MA	Yageo
Through-hole, TVS	P6KE6.8CA	TV1	1	TVSUP	Fairchild
Through-hole, TVS	P6KE22CA	TV33	1	TVSUP	Fairchild
Through-hole, Infrared Reader	HM238	U6	1	TSOP1838	Ableir
Through-hole, Infrared Sender	AT205B	D5	1	LED-5	Ableir
E-meter Case		201 Type 10 (60) A	1		QUANSHENG
Relay		GRT508FA 250 uΩ	1		GELEITE

Table 3. BOM (continued)

DESCRIPTION	VALUE	DESIGNATOR	PCS/UNIT	FOOTPRINT	MANUFACTURER
Current transformer		10 (60) / 5 MA	1		Shenke
PCB Board			1		

8.3 Layer Plots

To download the layer plots, see the design files at http://www.ti.com/tool/TIDM-TEMPCOMPENSATED-RTC.

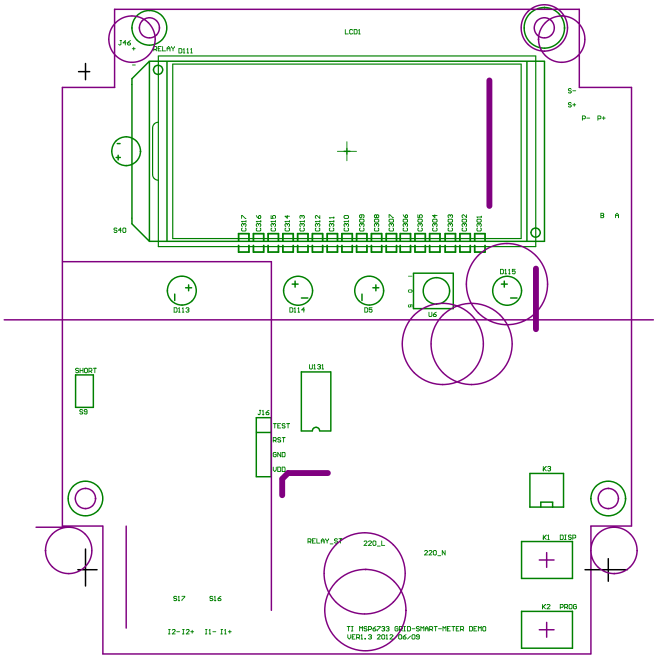


Figure 16. Top Silkscreen

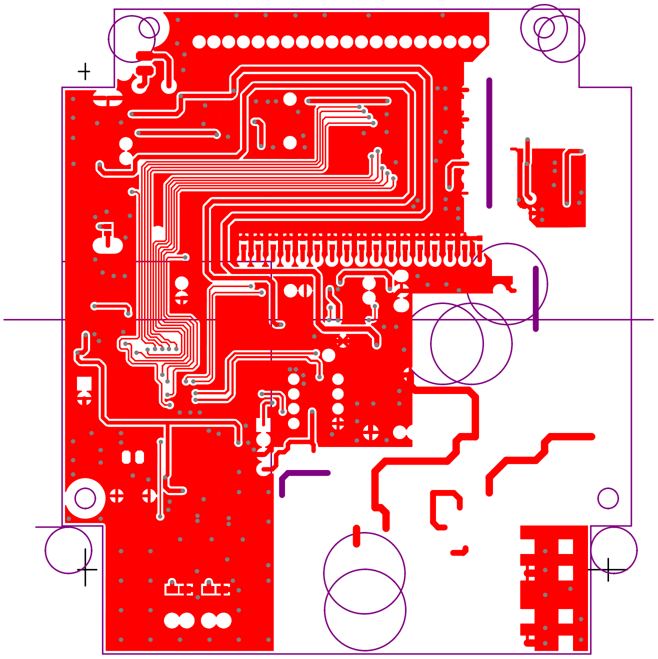


Figure 17. Top Layer

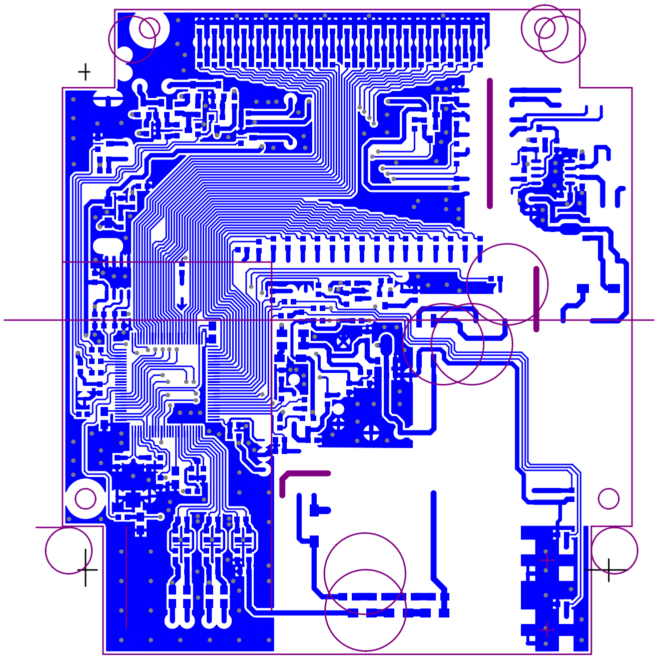


Figure 18. Bottom Layer

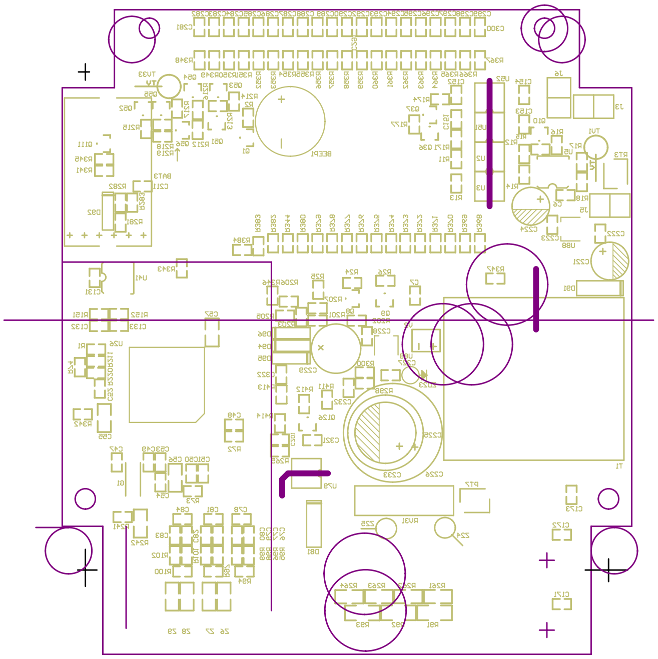


Figure 19. Bottom Silkscreen

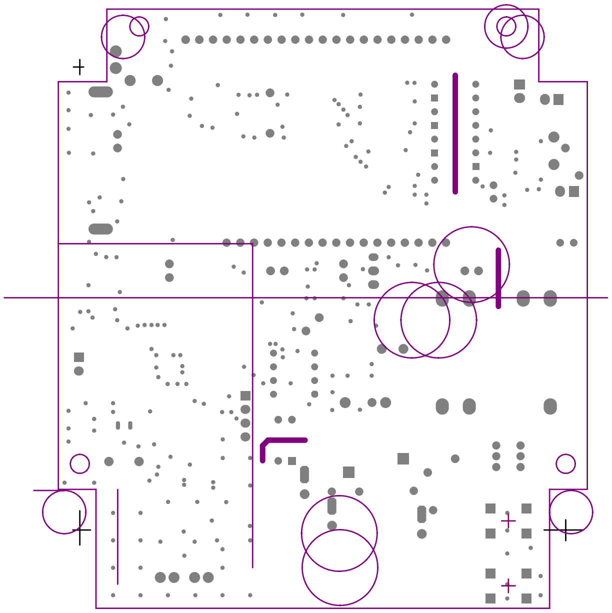


Figure 20. Mechanical Dimensions

8.4 Altium Project

To download the Altium project files, see the design files at http://www.ti.com/tool/TIDM-TEMPCOMPENSATED-RTC.

8.5 Gerber Files

To download the Gerber files, see the design files at http://www.ti.com/tool/TIDM-TEMPCOMPENSATED-RTC.

8.6 Software Files

To download the software files, see the design files at http://www.ti.com/tool/TIDM-TEMPCOMPENSATED-RTC.

8.7 References

1. *MSP430x5xx and MSP430x6xx Family User's Guide (Rev. K)* (SLAU208N)
2. *MSP430F673x, MSP430F672x Mixed Signal Microcontroller (Rev. B)* (MSP430f6736)

9 About the Author

ALEX CHENG joined TI in 2010 as an MCU FAE supporting MSP430 and industry metering applications in China. In 2011 he integrated the MCU SAE team for application system development into China. In 2014, he joined the Shenzhen EP FAE team to support general MCU and WCS products. Alex Cheng works across multiple product families and technologies to leverage the best solutions possible for system level application design and support. Alex Cheng graduated from Guilin University of Technology with a bachelor's degree, and he received his master's degree from Shenzhen University.

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Only those TI components that TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components that have ***not*** been so designated is solely at Buyer's risk, and Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

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