Application Note 2142
Using the Calibration Feature of the DS1340

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OVERVIEW

The DS1340 serial-access real-time clock (RTC) provides a software clock calibration function that allows an application to compensate for crystal and temperature variations. This application note describes how this feature is used to improve timekeeping accuracy.

REGISTER MAP

The DS1340's control register (address 07h) is used to control the operation of the FT/OUT pin and program the desired clock calibration. The register map of the DS1340 is detailed below.

Figure 1. Register Map

<table>
<tr><th>ADDRESS</th><th>BIT 7</th><th>BIT 6</th><th>BIT 5</th><th>BIT 4</th><th>BIT 3</th><th>BIT 2</th><th>BIT 1</th><th>BIT 0</th><th>FUNCTION</th><th>RANGE</th></tr>
<tr><td>00H</td><td>$\overline{EOSC}$</td><td colspan="3">10 Seconds</td><td colspan="4">Seconds</td><td>Seconds</td><td>00–59</td></tr>
<tr><td>01H</td><td>R/W</td><td colspan="3">10 Minutes</td><td colspan="4">Minutes</td><td>Minutes</td><td>00–59</td></tr>
<tr><td>02H</td><td>CEB</td><td>CB</td><td colspan="2">10 Hours</td><td colspan="4">HOURS</td><td>Century/ Hours</td><td>0–1; 00–23</td></tr>
<tr><td>03H</td><td>R/W</td><td>R/W</td><td>R/W</td><td>R/W</td><td>R/W</td><td colspan="3">Day</td><td>Day</td><td>01–07</td></tr>
<tr><td>04H</td><td>R/W</td><td>R/W</td><td colspan="2">10 Date</td><td colspan="4">Date</td><td>Date</td><td>00–31</td></tr>
<tr><td>05H</td><td>R/W</td><td>R/W</td><td>R/W</td><td>10 Month</td><td colspan="4">Month</td><td>Month</td><td>01–12</td></tr>
<tr><td>06H</td><td colspan="4">10 Year</td><td colspan="4">Year</td><td>Year</td><td>00–99</td></tr>
<tr><td>07H</td><td>OUT</td><td>FT</td><td>S</td><td>CAL4</td><td>CAL3</td><td>CAL2</td><td>CAL1</td><td>CAL0</td><td>Control</td><td></td></tr>
<tr><td>08H</td><td>TCS3</td><td>TCS2</td><td>TCS1</td><td>TCS0</td><td>DS1</td><td>DS0</td><td>ROUT1</td><td>ROUT0</td><td>Trickle Charger</td><td></td></tr>
<tr><td>09H</td><td>OSF</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>Flag</td><td></td></tr>
</table>

Output Control (OUT): This bit controls the output level of the FT/OUT pin when the FT bit is set to zero. If FT = 0, the logic level on the FT/OUT pin is 1 if OUT = 1 and is 0 if OUT = 0.

Frequency Test (FT): When this bit is 1, the FT/OUT pin toggles at a 512Hz rate. When FT is zero, the OUT bit controls the state of the FT/OUT pin.

Calibration Sign Bit (S): A logic 1 in this bit indicates positive calibration for the RTC. A logic 0 indicates negative calibration for the clock. See the *Crystal Calibration* section for a detailed description of the operation of these bits.

Calibration Bits (CAL4 to CAL0): These bits can be set to any value between 0 and 31 in binary form. See the *Crystal Calibration* section on for a detailed description of the operation of these bits.

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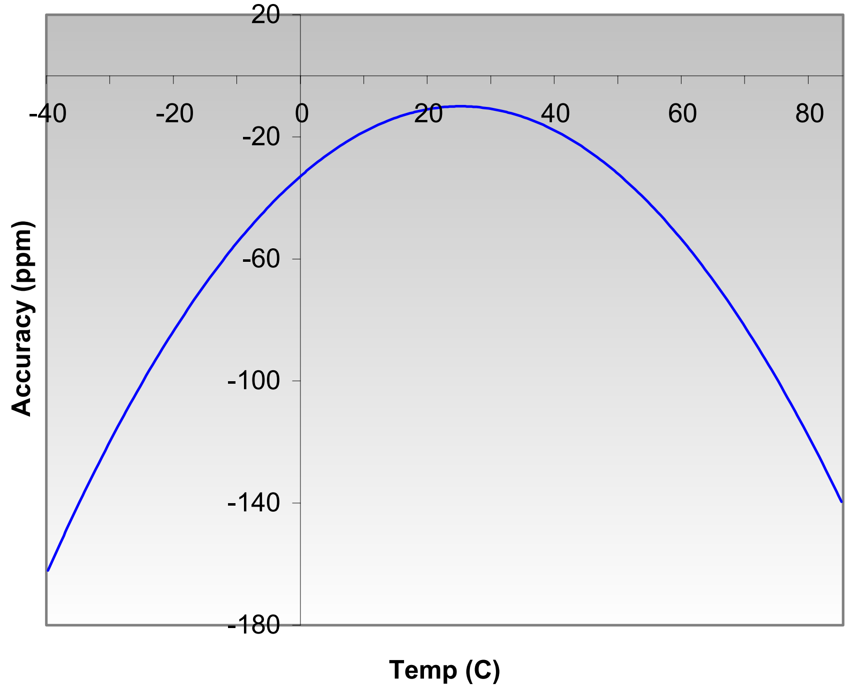
TYPICAL CRYSTAL BEHAVIOR

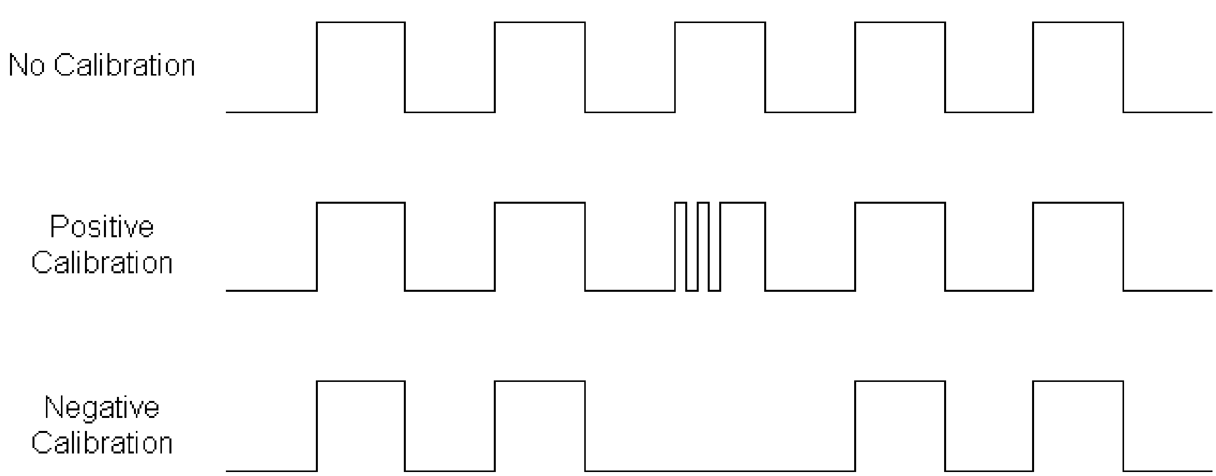
The crystal oscillator is one of the most accurate circuits for providing a fixed frequency. The accuracy of the RTC is dependent mainly on the accuracy of the crystal. Tuning fork crystals have a parabolic frequency across temperature as shown in Figure 2.

Figure 2. Typical Tuning Fork Crystal Behavior



CRYSTAL CALIBRATION

The purpose of the calibration circuit is to move this curve up or down to achieve zero parts per million (ppm) accuracy at a selected temperature. This is accomplished by adding or subtracting counts from the oscillator divider chain. The number of pulses blanked (subtracted for negative calibration) or inserted (added for positive calibration) is set by the 5-bit value loaded into the calibration bits (CAL4:CAL0) in the control register. Adding counts speeds the clock up (moves the crystal curve up) and subtracting counts slows the clock down (moves the crystal curve down). The following figure shows how the clock is adjusted for positive and negative calibration.



The calibration bits can be set to any value between 0 and 31 in binary form. Bit 5 of the control register (S) is the sign bit. A value of one for the S bit indicates positive calibration, while a value of zero represents negative calibration. Each calibration step either adds 512 or subtracts 256 oscillator cycles for every 125,829,120 actual 32,768Hz oscillator cycles (64 minutes). This equates to +4.068ppm or -2.034ppm of adjustment per calibration step. If the oscillator were running at exactly 32,768Hz, each of the 31 increments of the calibration bits would represent +10.7 or -5.35 seconds per month (+5.5 or -2.75 minutes per month). Figure 3 details the amount of adjustment for each value in the calibration register.

Figure 3. Calibration Adjustment Values

Sign	Calibration	Adjustment		Sign	Calibration	Adjustment	
		Accuracy (ppm)	Time (sec/month)			Accuracy (ppm)	Time (sec/month)
0	00000	0	0	1	00000	0	0
0	00001	-2	-5	1	00001	4	11
0	00010	-4	-11	1	00010	8	21
0	00011	-6	-16	1	00011	12	32
0	00100	-8	-21	1	00100	16	43
0	00101	-10	-27	1	00101	20	54
0	00110	-12	-32	1	00110	24	64
0	00111	-14	-37	1	00111	28	75
0	01000	-16	-43	1	01000	33	86
0	01001	-18	-48	1	01001	37	96
0	01010	-20	-54	1	01010	41	107
0	01011	-22	-59	1	01011	45	118
0	01100	-24	-64	1	01100	49	128
0	01101	-26	-70	1	01101	53	139
0	01110	-28	-75	1	01110	57	150
0	01111	-31	-80	1	01111	61	161
0	10000	-33	-86	1	10000	65	171
0	10001	-35	-91	1	10001	69	182
0	10010	-37	-96	1	10010	73	193
0	10011	-39	-102	1	10011	77	203
0	10100	-41	-107	1	10100	81	214
0	10101	-43	-112	1	10101	85	225
0	10110	-45	-118	1	10110	89	235
0	10111	-47	-123	1	10111	94	246
0	11000	-49	-128	1	11000	98	257
0	11001	-51	-134	1	11001	102	268
0	11010	-53	-139	1	11010	106	278
0	11011	-55	-144	1	11011	110	289
0	11100	-57	-150	1	11100	114	300
0	11101	-59	-155	1	11101	118	310
0	11110	-61	-161	1	11110	122	321
0	11111	-63	-166	1	11111	126	332

DETERMINING CLOCK ERROR

Before setting a calibration value, the amount of calibration required must be determined. When the FT bit (bit 6) of the control register is set, an uncalibrated 512Hz clock is provided on the FT/OUT pin (pin number 7). This frequency allows an application to determine the amount of frequency error for the crystal oscillator.

For example, if using the FT function, a reading of 512.01024Hz would indicate a +20ppm oscillator frequency error, requiring a -10 (00 1010) value to be loaded in the S bit and the five calibration bits. Writing to the control register clears the prescaler, which affects the 512Hz output momentarily (FT/OUT pin goes low). **Setting or changing the calibration bits does not affect the frequency on the FT/OUT output pin**.

SUMMARY

By using the new calibration feature of the DS1340, timekeeping accuracy provided by a crystal oscillator can be improved. While not providing automatic adjustment as temperature change, it still provides an incremental improvement in accuracy.