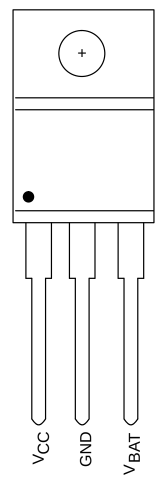
DALLAS SEMICONDUCTOR

DS1633
High–Speed Battery Recharger

FEATURES

- Recharges Lithium, NiCad, NiMH and Lead acid batteries
- Retains battery and power supply limits in onboard memory
- Serial 1–wire interface is used to program operating limits
- 3-pin TO–220 package
- Operating range 0°C to 70°C
- Applications include consumer electronics, portable/cellular phones, pagers, medical instruments, backup memory systems, security systems
- Configurable to operate with 5V or 6V supplies

PIN ASSIGNMENT TO–220



PIN DESCRIPTION

V_{CC}	–	Supply Voltage
V_{BAT}	–	Battery Output
GND	–	Ground

DESCRIPTION

The DS1633 Battery Recharger is designed to be a complete battery charging system for standard charge or trickle charge applications. It can be configured to be used with either 5V or 6V supplies and battery voltages as high as 4.7V (3.7V for 5V supplies). The device is flexible enough to be used with a variety of battery chemistries and cell capacities. It provides timer termination of standard charge and automatically shifts into trickle charge. Battery voltage can be monitored and charging terminated if it exceeds a preset maximum as a safety feature. The output load line can be specified as the usual constant current recharge with a voltage limit or it can be configured to approximate any practical load line. All parameters, such as power supply range, charge current load line, trickle charge rate, and timer setting, are programmed into nonvolatile memory using the battery pin as a 1–wire communication port. To ease the task of configuring the device to specific application needs, Dallas Semiconductor makes available a programming kit, the DS1633K, containing easy–to–use software and hardware for IBM personal computers.

The DS1633 is able to offer this flexibility due to its unique architecture (see Figure 1). The device monitors the battery voltage and adjusts the values of the output impedance (R_{TH}) and open circuit voltage (V_{OC}) it presents to the battery. These values can be adjusted at 32 user definable points (breakpoints) that occur roughly every 37mV. This allows the device to approximate a wide range of charging lines; it is not limited to constant current or even monotonically decreasing functions.

OPERATION

Normal Mode

Upon application of power, the DS1633 will perform an initialization cycle requiring eight seconds. During this period it will determine if a battery is connected to the battery input by applying a voltage through 5 KΩ output impedance and looking for a non–zero current flow out of the pin. If a battery is connected, the value of the battery voltage will be determined using a 7–bit A/D convertor. This value will be used to determine which of the 32 user–defined breakpoints should be used to set R_{TH} and V_{OC}. Generally, as the battery charges the battery voltage will increase. When the battery voltage reaches or exceeds each user–defined breakpoint, the values of R_{TH} and V_{OC} will be modified accordingly. The battery voltage is measured and adjustments are made every eight seconds. The battery detection is performed at one–second intervals. If the amount of time the battery has been charging exceeds the preset limit, the device will apply the V_{OC} and R_{TH} as before, but only for a fraction of the eight–second cycle time. This duty cycle can be as low as 1/64 or as high as 1. In this way trickle charge can be accomplished by time averaging a short pulse over a longer period. Refer to Figure 2 for a detailed flow diagram of normal operation.

PROGRAMMING MODE

Register Structure

To configure a DS1633 to operate with a unique load line the user must program a set of 25–bit internal registers (Table 1). The first 32 (0–31) of these registers contain the information needed to locate each breakpoint and what the R_{TH} and V_{OC} are at that breakpoint, as well as the duty cycle to be used after the optional timer has expired. The last (32) register contains the bits which select the system power supply level (5V or 6V), the timer option, and the time limit (2 to 32 hours in 2–hour increments).

BREAKPOINT REGISTER STRUCTURE

Break Point Voltage Field

The break point voltage field specifies the range of battery voltage over which the R_{TH}, V_{OC} and pulse frequency information contained in that register is valid. This information is valid when the battery voltage meets or exceeds the breakpoint value, but is less than the next breakpoint value:

$$V_{BPX} \leq V_{BAT} < V_{BP(x+1)}$$

The xth breakpoint voltage (V_{BPX}) is determined according to the following formula:

$$V_{BPX}(n) = (n/127)(4.699V) \text{ ; for } 0 \leq n \leq 127$$

The value for n is entered in the field as a 7–bit binary value, LSB first. For reliable operation the first (x=0) breakpoint should be programmed such that $V_{BP0} = 0$. Successive breakpoints should be programmed with increasing values, that is:

$$V_{BPX} < V_{BP(x+1)}$$

If not all of the available breakpoints are used, the unused points should be assigned the maximum V_{BP} value (n=127) of 4.699V with R_{TH} and V_{OC} set to their maximum values (5060Ω and 5.5V) and the duty cycle field set to its minimum or zero value.

OPEN CIRCUIT VOLTAGE FIELD

The open circuit voltage field specifies the value of V_{OC} to be applied to the battery. V_{OC} can be set for values between 1.3V and 5.5V. This field is entered as a 7–bit binary value, LSB first. The value of $V_{OC}(n)$ is determined as follows:

$$V_{OC}(n) = 1.3V + n(5.5V - 1.3V)/127 \text{ ; for } 0 \leq n \leq 127$$

For reliable operation of the battery detection circuitry, the minimum value of V_{OC} should be greater than the maximum battery voltage.

THEVENIN RESISTANCE FIELD

The Thevenin resistance field specifies the value of output resistance between the low impedance V_{OC} source and the battery pin. This resistance can have one of 128 values ranging from 5060Ω to 7.5Ω with a 5% difference in successive values. This field is entered as a 7–bit binary value, LSB first. The value of $R_{TH}(n)$ is determined as follows:

$$R_{TH}(n) = 7.5(0.95^{n-127}) \; ; \text{ for } 0 \le n \le 127$$

PULSE WIDTH FIELD

The pulse width field specifies the amount of time (PW) during each eight second charging and evaluation cycle that V_{OC} and R_{TH} will be applied after the optional timer has expired. PW can have one of 8 values ranging from 8 seconds to 0. The field is entered as a 3–bit binary value, LSB first. The value of PW is determined as follows:

$$PW(n) = 2^n/16 \; ; \text{ for } 1 \le n \le 7$$

$$PW(n) = 0 \; ; \text{ for } n = 0$$

CHARGE ON FIELD

This is a one bit field which specifies if V_{OC} and R_{TH} for this breakpoint are to be applied at all for the case of an unexpired timer. Its usefulness is in permitting certain breakpoints to be turned off if the battery voltage exceeds a maximum during standard charge. If the timer has expired or is not used, this is accomplished for those breakpoints using the 3 pulse width bits (PW = 000).

A one in this field means that the V_{OC} and R_{TH} are to be applied when the breakpoint is the current one.

CONFIGURATION REGISTER STRUCTURE

V_{TRIP} Field

This is a one–bit field which specifies the valid supply voltage for the device. A one in this field indicates a 6V system is being used and the part will not begin charging until the applied V_{CC} exceeds 5.7V. Conversely, a zero indicates a 5V system and charging will begin when V_{CC} exceeds 4.75V.

TIMER STATUS FIELD

This is a one bit field which indicates if the timer is to be used. A one in this field indicates that timer is used, a zero that it is not.

TIMER VALUE FIELD

This field specifies the maximum time (T_{MAX}) for standard or non–pulsed charging. During the period when the timer has not expired, V_{OC} and R_{TH} will be applied to the battery input if the charge on bit is a one. When the elapsed charge time exceeds the value in this register, V_{OC} and R_{TH} will be applied at a duty cycle determined by the PW field for each breakpoint. The field is entered as a 4–bit binary value, LSB first. The timer can have values from 2 to 32 hours, determined by the following:

$$T_{MAX}(n) = 2(n + 1) \; ; \text{ for } 0 \le n \le 15$$

PROGRAMMING OPERATION

The data for the 33 registers is stored in nonvolatile memory and can be written only once. All 33 registers must be programmed before any can be read. Note that although the configuration register contains only 6 bits, 25 bits are required to be entered; therefore, fill it with 19 0's. The registers are programmed sequentially, starting at register 0. As each register is programmed, an internal pointer moves to the next register until all 33 have been programmed. To enter the program/read mode, V_{CC} must be taken to 8V for a minimum of 1 ms and returned to 5V. The V_{BAT} pin is now configured to operate as a single wire I/O line. The hardware interface is shown in Figure 3.

RESET TIMING

To issue a reset to the device the V_{BAT} pin must be brought low and held low for a minimum of 480 µs after which it is released and will return to a high level through the internal pullup resistor. After the line is allowed to return high it must not be pulled low for at least 1 µs. Refer to Figure 4.

WRITE TIMING

A logic 0 is written by bringing the V_{BAT} pin low for at least 60 µs, but not more than 120 µs. A logic 1 is written by bringing the V_{BAT} pin low for at least 1 µs, but not more than 15 µs. After the line is allowed to return high it must not be pulled low for at least 60 µs. Refer to Figure 4.

READ TIMING

A read is performed by bringing the V_{BAT} pin low for at least 1 µs, but not more than 5 µs and then releasing it. A logic 1 is indicated by the pin returning high. The state of the V_{BAT} pin should be sampled at most 15 µs after V_{BAT} is pulled low. A high level indicates a read '1', a low level indicates a read '0'.

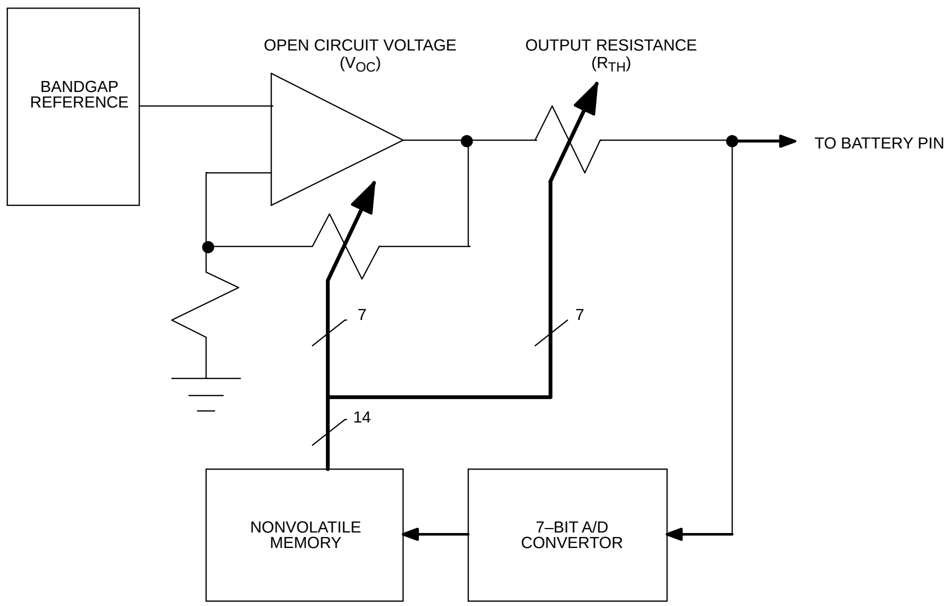
PROGRAMMING

To program the DS1633 the single line I/O must be enabled by bringing V_{CC} to 8V for at least 1 ms and then back to 5V. The first register can now be written. The register data must be preceded by 3 consecutive logic 1 write cycles. The register data can now be entered according to the write cycle timing detailed above, from LSB to MSB. To commit the data to the nonvolatile memory the V_{BAT} pin is brought to 12V, with V_{CC} at 8V, for at least 250 ms. When V_{BAT} is released and returns to 5V and a reset cycle is issued the device is ready for the next register. Be careful not to issue multiple resets as this will move the pointer. This sequence is repeated until all 33 registers are programmed. When all registers have been programmed, the DS1633 disables the serial interface and begins normal operation.

VERIFICATION

To verify the data contained in the registers the single line I/O must be enabled by bringing V_{CC} to 8V for at least 1 ms. Unlike the programming operation, the read operation allows random access of the registers. A read cycle is preceded by 4 logic ones, a 6–bit register address, entered LSB first, and 18 logic ones. The device will now output the contents of the register, LSB first, on the next 25 read cycles. To read another register, issue a reset and repeat the sequence.

SIMPLIFIED BLOCK DIAGRAM Figure 1

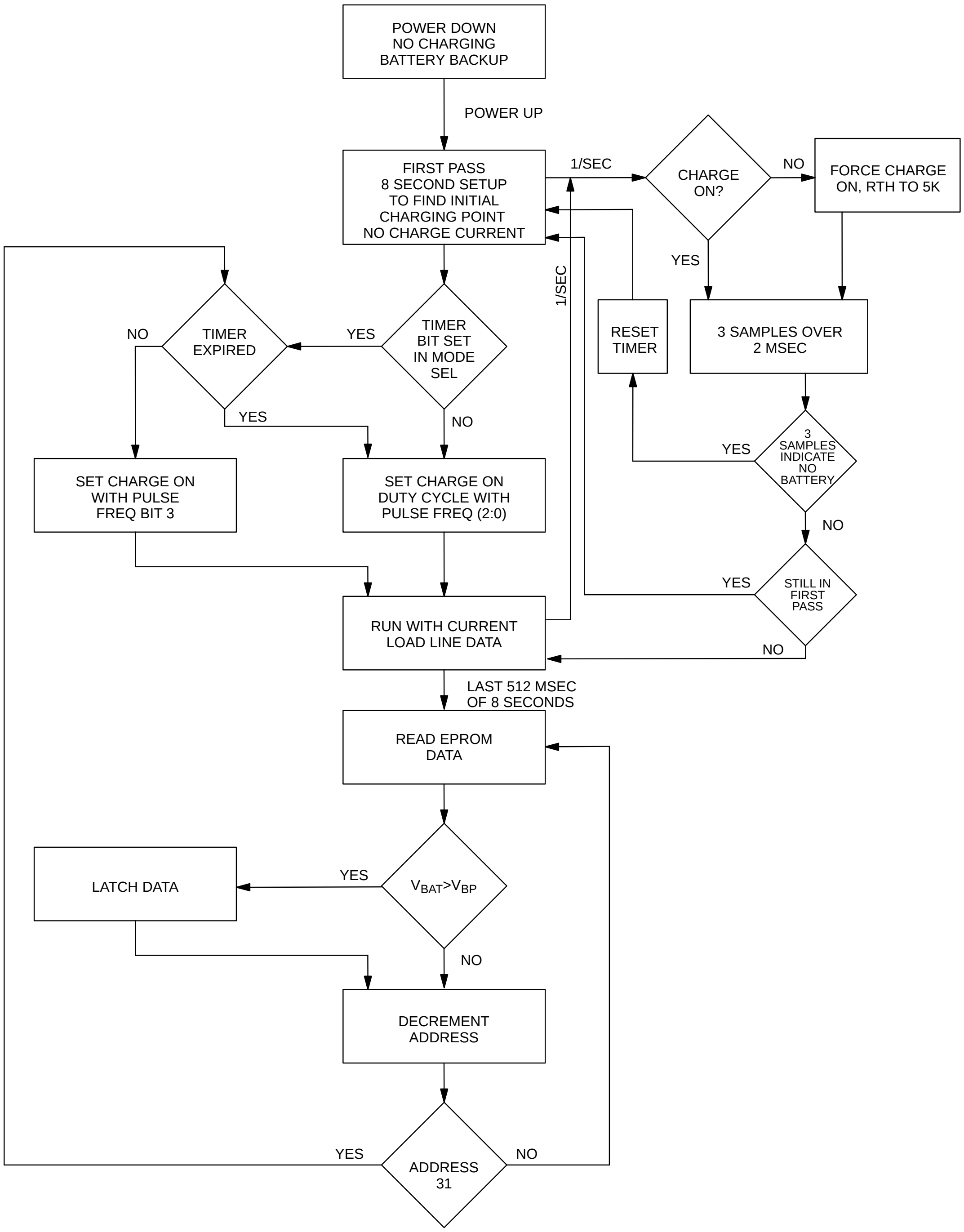


DS1633 REGISTER STRUCTURE Table 1

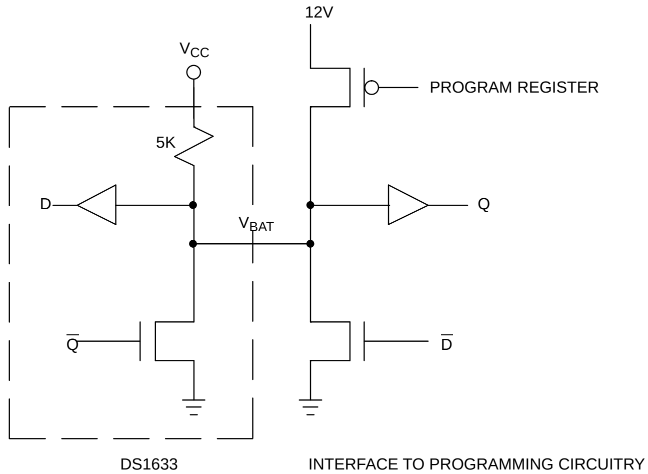
MSB — **DS1633 MEMORY ARRAY MAP** — **LSB**

REGISTER	CHARGE ON	PULSE WIDTH	THEVENIN RESISTANCE FIELD	OPEN CIRCUIT VOLTAGE	BREAKPOINT VOLTAGE
0	CO_0	PW_0	R_{TH0}	V_{OC0}	V_{BP0}
1	↓	↓	↓	↓	↓
2					
3					
•					
•					
•					
30					
31	CO_{31}	PW_{31}	R_{TH31}	V_{OC31}	V_{BP31}
32	MUST FILL UNUSED BITS WITH 0'S				TIMER VALUE / TIMER STATUS / V_{TRIP}

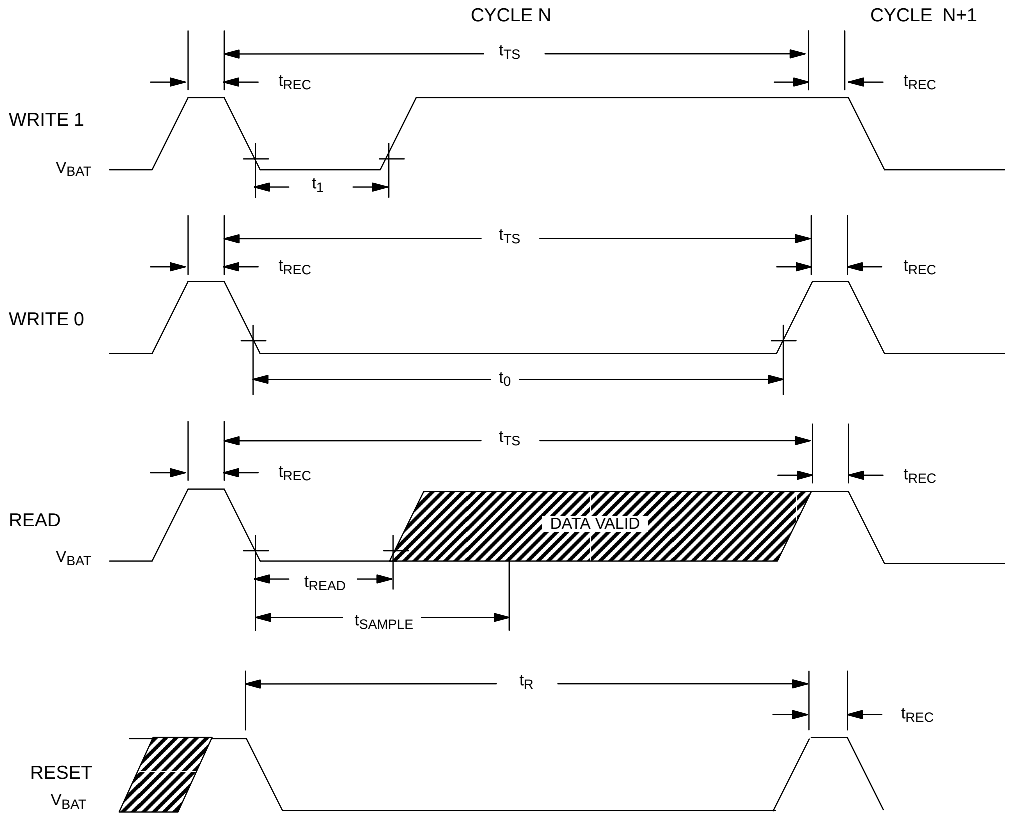
DS1633 OPERATION FLOW CHART Figure 2



HARDWARE INTERFACE FOR PROGRAMMING Figure 3



I/O SIGNAL TIMING Figure 4



REGISTER VALUE CROSS REFERENCE Table 2

HEX	DEC	R_{TH}	V_{OC}	V_{BP}
00	0	5.060E+03	1.30	0.000
01	1	4.807E+03	1.33	0.037
02	2	4.567E+03	1.37	0.074
03	3	4.338E+03	1.40	0.111
04	4	4.122E+03	1.43	0.148
05	5	3.915E+03	1.47	0.185
06	6	3.720E+03	1.50	0.222
07	7	3.534E+03	1.53	0.259
08	8	3.357E+03	1.56	0.296
09	9	3.189E+03	1.60	0.333
0A	10	3.030E+03	1.63	0.370
0B	11	2.878E+03	1.66	0.407
0C	12	2.734E+03	1.70	0.444
0D	13	2.598E+03	1.73	0.481
0E	14	2.468E+03	1.76	0.518
0F	15	2.344E+03	1.80	0.555
10	16	2.227E+03	1.83	0.592
11	17	2.116E+03	1.86	0.629
12	18	2.010E+03	1.90	0.666
13	19	1.909E+03	1.93	0.703
14	20	1.814E+03	1.96	0.740
15	21	1.723E+03	1.99	0.777
16	22	1.637E+03	2.03	0.814
17	23	1.555E+03	2.06	0.851
18	24	1.478E+03	2.09	0.888
19	25	1.404E+03	2.13	0.925
1A	26	1.333E+03	2.16	0.962
1B	27	1.267E+03	2.19	0.999
1C	28	1.203E+03	2.23	1.036
1D	29	1.143E+03	2.26	1.073
1E	30	1.086E+03	2.29	1.110
1F	31	1.032E+03	2.33	1.147
20	32	9.802E+02	2.36	1.184
21	33	9.312E+02	2.39	1.221
22	34	8.846E+02	2.42	1.258
23	35	8.404E+02	2.46	1.295
24	36	7.984E+02	2.49	1.332
25	37	7.585E+02	2.52	1.369

HEX	DEC	R_{TH}	V_{OC}	V_{BP}
26	38	7.205E+02	2.56	1.406
27	39	6.845E+02	2.59	1.443
28	40	6.503E+02	2.62	1.480
29	41	6.178E+02	2.66	1.517
2A	42	5.869E+02	2.69	1.554
2B	43	5.575E+02	2.72	1.591
2C	44	5.297E+02	2.76	1.628
2D	45	5.032E+02	2.79	1.665
2E	46	4.780E+02	2.82	1.702
2F	47	4.541E+02	2.85	1.739
30	48	4.314E+02	2.89	1.776
31	49	4.098E+02	2.92	1.813
32	50	3.894E+02	2.95	1.850
33	51	3.699E+02	2.99	1.887
34	52	3.514E+02	3.02	1.924
35	53	3.338E+02	3.05	1.961
36	54	3.171E+02	3.09	1.998
37	55	3.013E+02	3.12	2.035
38	56	2.862E+02	2.15	2.072
39	57	2.719E+02	3.19	2.109
3A	58	2.583E+02	3.22	2.146
3B	59	2.454E+02	3.25	2.183
3C	60	2.331E+02	3.28	2.220
3D	61	2.215E+02	3.32	2.257
3E	62	2.104E+02	3.35	2.294
3F	63	1.999E+02	3.38	2.331
40	64	1.899E+02	3.42	2.368
41	65	1.804E+02	3.45	2.405
42	66	1.714E+02	3.48	2.442
43	67	1.628E+02	3.52	2.479
44	68	1.547E+02	3.55	2.516
45	69	1.469E+02	3.58	2.553
46	70	1.396E+02	3.61	2.590
47	71	1.326E+02	3.65	2.627
48	72	1.260E+02	3.68	2.664
49	73	1.197E+02	3.71	2.701
4A	74	1.137E+02	3.75	2.738
4B	75	1.080E+02	3.78	2.775

HEX	DEC	R_{TH}	V_{OC}	V_{BP}
4C	76	1.026E+02	3.81	2.812
4D	77	9.747E+01	3.85	2.849
4E	78	9.260E+01	3.88	2.886
4F	79	8.797E+01	3.91	2.923
50	80	8.357E+01	3.95	2.960
51	81	7.939E+01	3.98	2.997
52	82	7.542E+01	4.01	3.034
53	83	7.165E+01	4.04	3.071
54	84	6.807E+01	4.08	3.108
55	85	6.467E+01	4.11	3.145
56	86	6.143E+01	4.14	3.182
57	87	5.836E+01	4.18	3.219
58	88	5.544E+01	4.21	3.256
59	89	5.267E+01	4.24	3.293
5A	90	5.004E+01	4.28	3.330
5B	91	4.753E+01	4.31	3.367
5C	92	4.516E+01	4.34	3.404
5D	93	4.290E+01	4.38	3.441
5E	94	4.076E+01	4.41	3.478
5F	95	3.873E+01	4.44	3.515
60	96	3.678E+01	4.47	3.552
61	97	3.494E+01	4.51	3.589
62	98	3.320E+01	4.54	3.626
63	99	3.154E+01	4.57	3.663
64	100	2.996E+01	4.61	3.700
65	101	2.846E+01	4.64	3.737

HEX	DEC	R_{TH}	V_{OC}	V_{BP}
66	102	2.704E+01	4.67	3.774
67	103	2.569E+01	4.71	3.811
68	104	2.440E+01	4.74	3.848
69	105	2.318E+01	4.77	3.885
6A	106	2.202E+01	4.81	3.922
6B	107	2.092E+01	4.84	3.959
6C	108	1.988E+01	4.87	3.996
6D	109	1.888E+01	4.90	4.033
6E	110	1.794E+01	4.94	4.070
6F	111	1.704E+01	4.97	4.107
70	112	1.619E+01	5.00	4.144
71	113	1.538E+01	5.04	4.181
72	114	1.461E+01	5.07	4.218
73	115	1.388E+01	5.10	4.255
74	116	1.319E+01	5.14	4.292
75	117	1.253E+01	5.17	4.329
76	118	1.190E+01	5.20	4.366
77	119	1.131E+01	5.24	4.403
78	120	1.074E+01	5.27	4.440
79	121	1.020E+01	5.30	4.477
7A	122	9.693E+00	5.33	4.514
7B	123	9.208E+00	5.37	4.551
7C	124	8.748E+00	5.40	4.588
7D	125	8.310E+00	5.43	4.625
7E	126	7.895E+00	5.47	4.662
7F	127	7.500E+00	5.50	4.699

ABSOLUTE MAXIMUM RATINGS*

Voltage on Any Pin Relative to Ground	-1.0V to +7.0V
Operating Temperature	0°C to 70°C
Storage Temperature	–55°C to +125°C
Soldering Temperature	260°C for 10 seconds

* This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

RECOMMENDED DC OPERATING CONDITIONS

(0°C to 70°C)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
5V Mode Supply Voltage, Operation	V_{CC1}	4.75	5	6.5	V	1,2
6V Mode Supply Voltage, Operation	V_{CC2}	5.7	6	6.5	V	1,3,4
Supply Voltage, V_{BAT}, Programming	V_{BATP}	12	12	13	V	
I_{BAT}, Programming	I_{BATP}			100	μA	
V_{CC} Supply Voltage, Programming	V_{CC3}	8		8.5	V	
Logic 1 Input	V_{IH}	2.0	–	V_{CC}+0.3	V	
Logic 0 Input	V_{IL}	–0.3	–	+0.8	V	

DC ELECTRICAL CHARACTERISTICS

(0°C to 70°C; V_{CC}=5.75V)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Supply Current, Operation Mode	$I_{CC1,2}$			1	mA	6
Supply Current, Programming Mode	I_{CC3}			10	mA	
Output Low, Voltage	V_{OL}			0.4	V	
Output Low, Current	I_{OL}	1			mA	
V_{BAT} Leakage Current with V_{CC} at 0V	I_{BAT}			100	nA	5
Pullup resistance on I/O	R_{PU}		5K			
Breakpoint Voltage (n=0)	V_{BP}(0)		0		V	
Breakpoint Voltage (n=127)	V_{BP}(127)	4.649	4.699	4.749	V	
Open Circuit Voltage (n=0)	V_{OC}(0)		1.3		V	
Open Circuit Voltage (n=127)	V_{OC}(127)	5.45	5.50	5.55	V	
Thevenin Resistance (n=0)	R_{TH}(0)		7.5		Ω	7
Thevenin Resistance (n=127)	R_{TH}(127)	4933	5060	5187	Ω	7
Timer Value (n=0)	T_{MAX}(0)	1.8	2	2.2	hours	
Timer Value (n=15)	T_{MAX}(127)	28.8	32	35.2	hours	

AC ELECTRICAL CHARACTERISTICS: DATA TRANSMISSION PARAMETERS

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Reset Active	t_R	480			µs	
Logic 1 Active Low	t_1	1		15	µs	
Logic 0 Active Low	t_0	60		120	µs	
Read Enable Time	t_{READ}	1		5	µs	
Time from Read Enable to I/O Line Sampling	t_{SAMPLE}			15	µs	
Data Transfer Window	t_{TS}	60		120	µs	
Active Signal Pulse Width, Data I/O	t_{PW}	60		120	µs	
Recovery Time Between Windows	t_{REC}	1			µs	
Programming Pulse Width, V_{BAT}	t_{PRG}	250			ms	

NOTES:

1. All voltages referenced to ground.
2. 5V operation conditions.
3. 6V operation conditions.
4. For any $V_{OCMAX} \geq 4.5V$, $V_{TRIP} = 5.7V$ (6V operation) must be used.
5. High impedance isolation between V_{BAT} and V_{CC} with $V_{CC}=0$ is $\geq 45G\Omega$.
6. Does not include current supplied to the battery pin.
7. At 25°C, R_{TH} has a positive temperature coefficient of approximately 800 ppm/°C.