DS2755

High-Accuracy Battery Fuel Gauge with Snapshot

www.maxim-ic.com

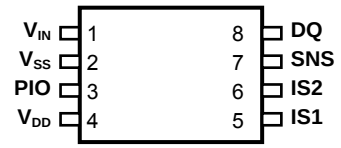
FEATURES

- Snapshot Mode Allows Instantaneous Power Measurement
- Accurate Current Measurement for Coulomb Counting (Current Accumulation)
  - 2% ±4μV over ±64mV Input Range
  - 2% ±200μA over ±3.2A Range Using a 20mΩ Sense Resistor
- Current Measurement
  - 9-Bit Bidirectional Snapshot Measurement
  - 12-Bit Bidirectional Average Updated Every 88ms
  - 15-Bit Bidirectional Average Updated Every 2.8s
- Voltage Measurement
  - 9-Bit Snapshot Measurement
  - 10-Bit Measurement Updated Every 4ms
- Temperature Measurement
  - 10-Bit Measurement, 0.125°C Resolution Using Integrated Sensor
- Host Alerted When Accumulated Current or Temperature Exceeds User-Selectable Limits
- 96 Bytes of Lockable EEPROM
- 8 Bytes of General-Purpose SRAM
- Dallas 1-Wire® Interface with Unique 64-Bit Device Address with Standard 16kbps or Overdrive 142kbps Timing
- 3mm Dimension of 8-Pin TSSOP Package Allows Mounting on Side of Thin Prismatic Li+ and Li+/Polymer Cells

APPLICATIONS

Cell Phones
Digital Cameras
Smartphones
PDAs
Portable Consumer Products

PIN CONFIGURATION



DS2755E
8-Pin TSSOP Package

DESCRIPTION

The DS2755 high-precision battery fuel gauge is a data-acquisition and information-storage device tailored for cost-sensitive and space-constrained 1-cell Li+/polymer battery-pack applications. The DS2755 provides the key hardware components required to accurately estimate remaining capacity by integrating low-power, precision measurements of temperature, voltage, current, and current accumulation, as well as nonvolatile (NV) data storage, into the small footprint of a 3.0mm x 4.4mm 8-pin TSSOP package.

Through its 1-Wire interface, the DS2755 gives the host system read/write access to status and control registers, instrumentation registers, and general-purpose data storage. Each device has a unique factory-programmed 64-bit net address that allows it to be individually addressed by the host system, supporting multibattery operation.

ORDERING INFORMATION

PART	MARKING	TEMP RANGE	DESCRIPTION
DS2755E+	2755	-20°C to +70°C	8-Pin TSSOP, Lead Free
DS2755E+T&R	2755	-20°C to +70°C	DS2755E+ on Tape-and-Reel

1-Wire is a registered trademark of Dallas Semiconductor.

Note: *Some revisions of this device may incorporate deviations from published specifications known as errata. Multiple revisions of any device may be simultaneously available through various sales channels. For information about device errata, click here: www.maxim-ic.com/errata.*

DESCRIPTION (CONTINUED)

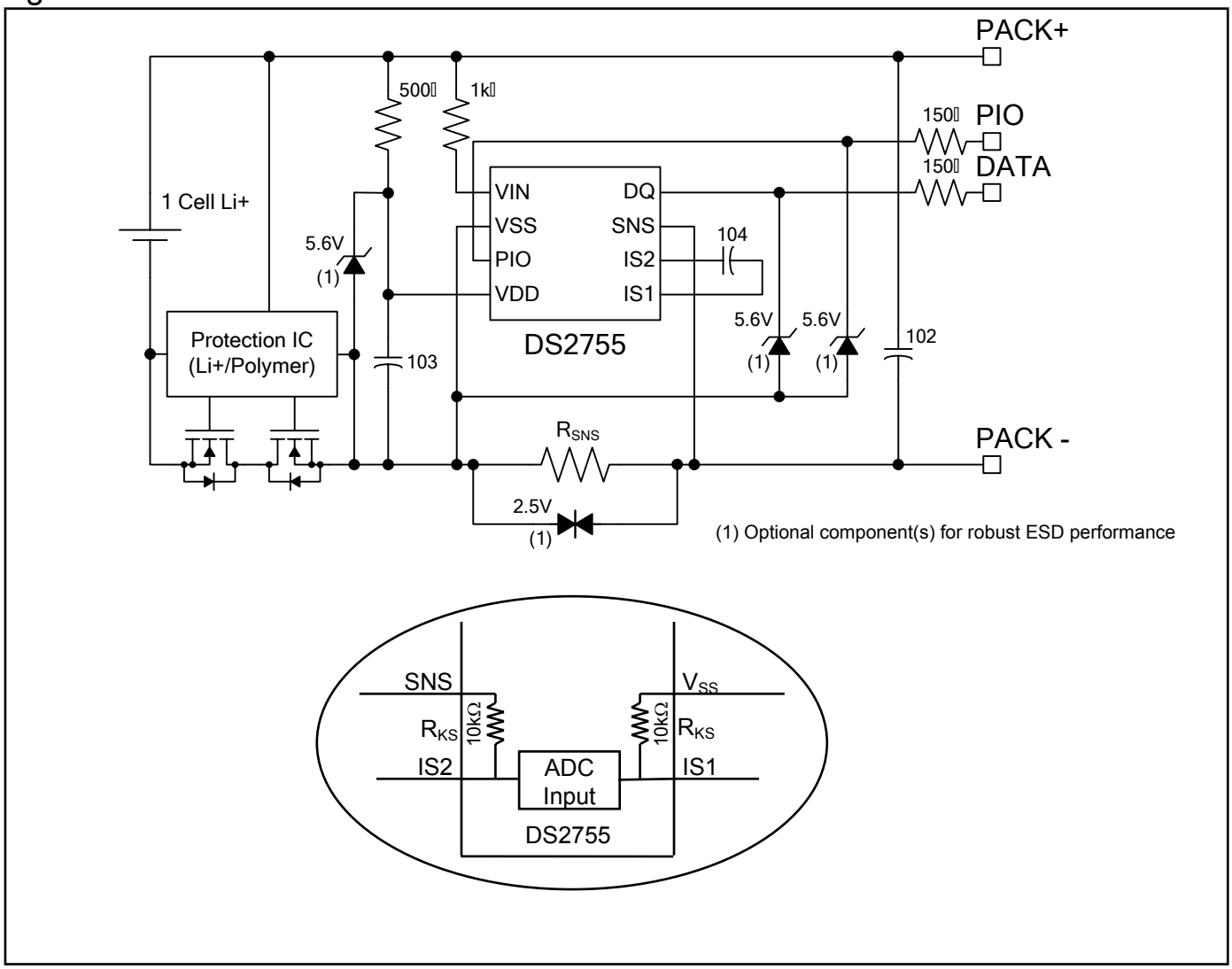
The DS2755 performs temperature, voltage, and current measurement to a resolution sufficient to support process-monitoring applications such as battery charge control and remaining capacity estimation. Temperature is measured using an on-chip sensor, eliminating the need for a separate thermistor. Bidirectional current measurement supporting current accumulation (coulomb counting) is accomplished using an external current sense resistor.

The host system can configure the DS2755 to signal critical conditions to reduce polling overhead. The interrupt fires when programmable upper and lower thresholds of temperature or coulomb count are crossed. The user can select either the DQ pin or PIO pin as the interrupt signal.

The programmable I/O pin allows the host system to sense and control other electronics in the pack, including switches, vibration motors, speakers, and LEDs, or the I/O pin can be configured as an interrupt output.

Three types of memory are provided on the DS2755 for battery information storage: EEPROM, lockable EEPROM, and SRAM. EEPROM memory saves important battery data in true NV memory that is unaffected by severe battery depletion, accidental shorts, or ESD events. Lockable EEPROM becomes ROM when locked to provide additional security for unchanging battery data. SRAM provides inexpensive storage for temporary data.

Figure 1. **APPLICATION EXAMPLE**



ABSOLUTE MAXIMUM RATINGS*

Voltage on PIO Pin, Relative to V_{SS}	-0.3V to +12V
Voltage on All Other Pins, Relative to V_{SS}	-0.3V to +6V
Continuous Sink Current, DQ, PIO	12mA
Operating Temperature Range	-40°C to +85°C
Storage Temperature Range	-55°C to +125°C
Soldering Temperature	See J-STD-020 Specification

** 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

($2.5V \le V_{DD} \le 5.5V$, T_A = -20°C to +70°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage	V_{DD}	(Note 1)	2.5		5.5	V
Data Pin	DQ	(Note 1)	-0.3		+5.5	V
V_{IN} Pin	V_{IN}	(Note 1)	-0.3		+5.5	V

DC ELECTRICAL CHARACTERISTICS

($2.5V \le V_{DD} \le 5.5V$, T_A = -20°C to +70°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Active Current	I_{ACTIVE}	DQ = V_{DD}, EEC bit = 0, 0°C to +50°C, 2.5V < V_{DD} < 4.2V		75	100	µA
		DQ = V_{DD}, EEC bit = 0			110	
Sleep-Mode Current	I_{SLEEP}	DQ = 0V (Note 3)		1	2	µA
Current Measurement Input Range	$V_{IS1-IS2}$	(Note 2)	±64			mV
Current Register Offset Error	I_{OERR}	(Note 5)			±7.813	µV
Current Gain Error	I_{GERR}	(Note 2, 6)			±1	%I reading
24 Hour Accumulated Current Error	q_{CA}	$V_{IS1-IS2}$ = 0, OBEN set, (Note 2, 7, 4)	-200	-100	0	µVhr
Current Sampling Frequency	f_{SAMP}			1456		Hz
IS1-VSS, IS2-SNS Filter Resistors	R_{KS}	+25°C		10		kΩ
Input Resistance: V_{IN}	R_{IN}	V_{IN} = V_{DD}	5			MΩ
Voltage Offset Error	V_{OERR}	(Note 8)			±5	mV
Voltage Gain Error	V_{GERR}				±2	%V reading
Temperature Error	T_{ERR}	(Note 9)			±3	°C
Input Logic High: DQ, PIO	V_{IH}	(Note 1)	1.5			V
Input Logic Low: DQ, PIO	V_{IL}	(Note 1)			0.4	V
Output Logic Low: DQ, PIO	V_{OL}	I_{OL} = 4mA (Note 1)			0.4	V
DQ Pulldown Current	I_{PD}			1		µA
DQ Capacitance	C_{DQ}				60	pF
DQ Low-to-Sleep Time	t_{SLEEP}		2.1			s
Undervoltage Detect	V_{UV}	(Note 1)	2.45	2.5	2.55	V
Undervoltage Delay	t_{UVD}		90	100	110	ms
Internal Timebase Accuracy	t_{ERR}	0°C to +50°C (Note 10)		±1	±2	%
		-20°C to +70°C			±3	

ELECTRICAL CHARACTERISTICS—1-WIRE INTERFACE

($2.5V \le V_{DD} \le 5.5V$, T_A = -20°C to +70°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Snapshot Trigger 0	t_{SWL}		1		16	µs
Snapshot Delay	t_{SDLY}		80	100	120	µs
STANDARD TIMING						
Time Slot	t_{SLOT}		60		120	µs
Recovery Time	t_{REC}		1			µs
Write-0 Low Time	t_{LOW0}		60		119	µs
Write-1 Low Time	t_{LOW1}		1		15	µs
Read Data Valid	t_{RDV}				15	µs
Reset Time High	t_{RSTH}		480			µs
Reset Time Low	t_{RSTL}		480		960	µs
Presence-Detect High	t_{PDH}		15		60	µs
Presence-Detect Low	t_{PDL}		60		240	µs
Interrupt Time Low	t_{IL}		480		1920	µs
OVERDRIVE TIMING						
Time Slot	t_{SLOT}		6		16	µs
Recovery Time	t_{REC}		1			µs
Write-0 Low Time	t_{LOW0}		6		16	µs
Write-1 Low Time	t_{LOW1}		1		2	µs
Read Data Valid	t_{RDV}				2	µs
Reset Time High	t_{RSTH}		48			µs
Reset Time Low	t_{RSTL}		48		80	µs
Presence-Detect High	t_{PDH}		2		6	µs
Presence-Detect Low	t_{PDL}		8		24	µs
Interrupt Time Low	t_{IL}		48		192	µs

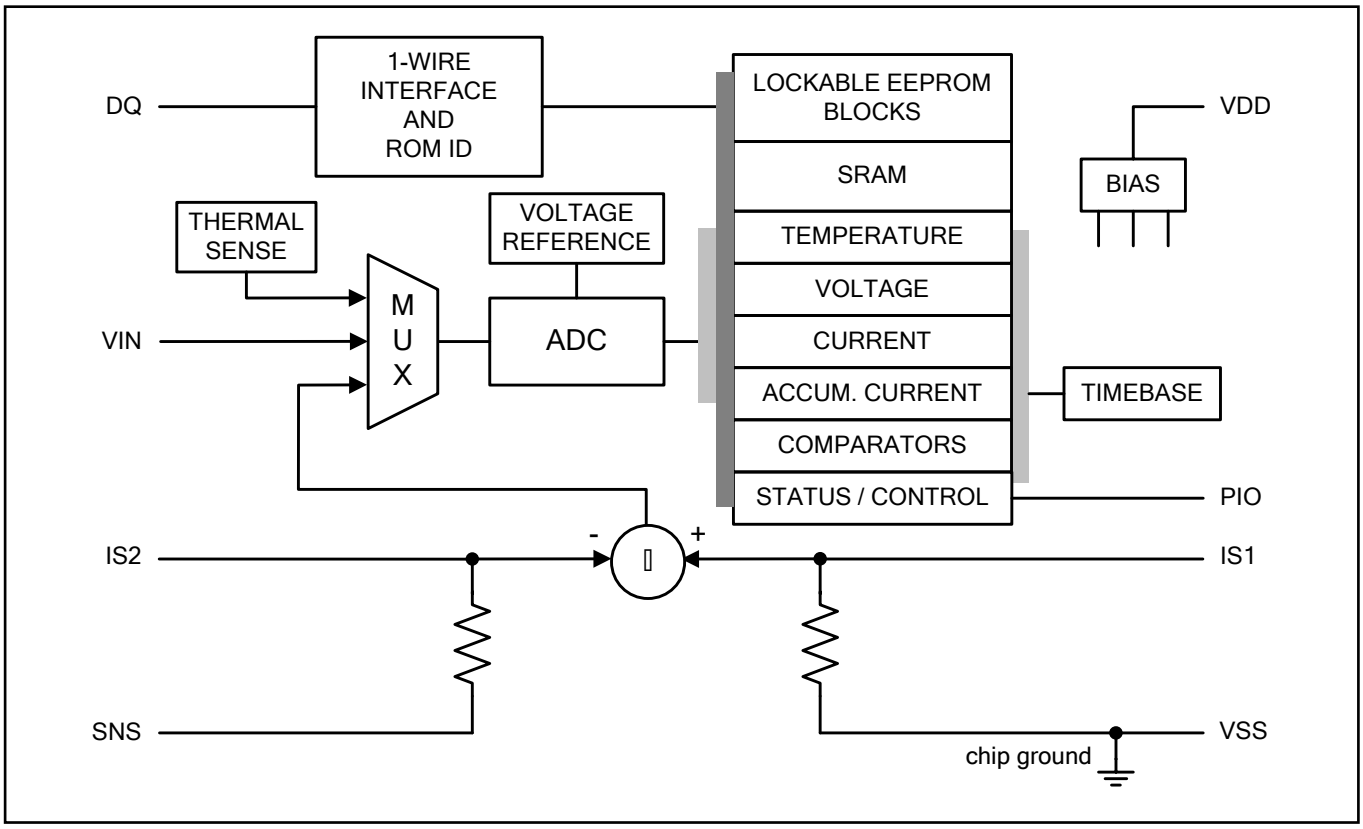
EEPROM RELIABILITY SPECIFICATION

($2.5V \le V_{DD} \le 5.5V$, T_A = -20°C to +70°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Copy to EEPROM Time	t_{EEC}			2	10	ms
EEPROM Copy Endurance	N_{EEC}	(Note 11)	50,000			cycles

Note 1: All voltages are referenced to V_{SS}.
Note 2: Specifications relative to V_{IS1} - V_{IS2}.
Note 3: The DS2755 requires a maximum of 25µAH of charge to transition into sleep mode.
Note 4: Summation of worst case time base and current measurement sampling errors.
Note 5: Continuous offset cancellation corrects offset errors in the current measurement system. Individual values reported by the Current register have a maximum offset of ±0.5 LSb's (±7.8125µV). Individual values reported in the Average Current register have a maximum offset of ±2 LSb's (±7.8125µV).
Note 6: Current Gain Error specifies the gain error in the Current register value compared to a reference voltage between IS1 and IS2. The DS2755 does not compensate for sense resistor characteristics, and any error terms arising from the sense resistor should be taken into account when calculating total current measurement error.
Note 7: Achieving the 24 Hour Accumulated Current Error assumes positive offset accumulation blanking is enabled (OBEN bit set) and can require a one time 3.5s in-system calibration after mounting to the printed circuit board. Variations in temperature and supply voltage are compensated for by periodic offset corrections performed automatically during *Active* mode operation.
Note 8: Voltage offset measurement is with respect to 4.2V at +25°C.
Note 9: Self heating due to output pin loading and sense resistor power dissipation can alter the Temperature reading from ambient conditions.
Note 10: Typical value for t_{ERR} valid at 3.7V and +25°C. t_{ERR} applies to all internal timings (ex. f_{SAMP}, t_{SLEEP}, t_{UVD}) except for the 1-Wire Interface timings.
Note 11: Four year data retention at +50°C.

Figure 2. **FUNCTIONAL DIAGRAM**



DETAILED PIN DESCRIPTION

PIN	NAME	DESCRIPTION
1	VIN	Battery voltage sense input. Voltage measurement performed on VIN input and displayed in Voltage Register.
2	VSS	Device ground and current sense resistor connection. VSS attaches to battery end of sense resistor.
3	PIO	General purpose programmable I/O pin or optional interrupt output.
4	VDD	Input supply: +2.5V to +5.5V input range. Bypass VDD to VSS with 0.1μF.
5	IS1	Current sense filter input 1
6	IS2	Current sense filter input 2
7	SNS	Sense resistor connection. SNS attaches to pack end of current sense resistor.
8	DQ	Serial interface data I/O pin. Bidirection data transmit and receive at 16kbps or 143kbps. Optional interrupt output.

POWER MODES

The DS2755 has two power modes: *Active* and *Sleep*. While in *Active* mode, the DS2755 continuously measures current, voltage and temperature. Current accumulation and monitoring for under voltage also occur continuously in *Active* mode. In *Sleep* mode, the DS2755 ceases these activities. The DS2755 enters *Sleep* mode when PMOD = 1 **AND** either of the following occur:

- the DQ line is low for longer than t_{SLEEP} (minimum 2.1s)
  (DQ low used indicate that the pack has been disconnected or that the host system is signaling the DS2755 to enter *Sleep* mode.)

the UVEN bit in the Status Register is set to 1 **AND** the voltage on V_{IN} drops below undervoltage threshold V_{UV} for t_{UVD}

The DS2755 returns to *Active* mode when the DQ line is pulled from a low-to-high state and the voltage on V_{IN} is above V_{UV}. The factory default for the DS2755 is UVEN = PMOD = 0. The DS2755 defaults to *Active* mode when power is first applied.

CURRENT MEASUREMENT AND ACCUMULATION

The DS2755 current measurement system is designed to provide timely data on charge and discharge current at a moderate resolution level while simultaneously accumulating high resolution average data to support accurate coulomb counting. Current is measured with an Analog-to-Digital Converter (ADC) by sampling the voltage drop across a series sense resistor, R_{SNS}, connected between SNS and VSS. Individual current samples are taken every 687μs (1456^{-1} Hz). Multiple samples are averaged to report Current and Average Current values, and accumulated for coulomb counting.

Current Measurement

The voltage signal developed across the sense resistor (between SNS and VSS) is differentially sampled by the ADC inputs via internal 10kΩ resistors connected between VSS and IS1, and SNS and IS2. Isolating the ADC inputs (IS1 and IS2 pins) from the sense resistor with 10kΩ facilitates the use of an RC filter by adding a single external capacitor. The RC filter extends the input range beyond ±64mV in pulse load or pulse charge applications. The ADC accurately measures large peak signals as long as the differential signal level at IS1 and IS2 does not exceed ±64mV.

The Current register operates in two modes, normal and snapshot. In normal mode, the Current register reports the average of 128 individual current samples every 88ms. The reported value represents the average current during the 88ms measurement period. The Average Current register reports the average of 4096 current samples and is updated every 2.8s.

In snapshot mode, the Current register holds the current measured immediately following the snapshot trigger. Current measurements resume immediately after the snapshot value is obtained, however, the SNAP bit must be cleared to re-enable normal mode current reporting in the Current register. The Average Current register continues to be updated while the SNAP bit is set. Current accumulation also continues while SNAP is set. Although a small error is introduced into both the Average Current and Accumulated Current values by the current sample timing discontinuity introduced with each trigger of the Snapshot mode, use of Snapshot once every 5s does not produce a significant error.

The following register formats specify the update interval and units for the Current and Average Current registers. Values are posted in two's compliment format. Positive values represent charge currents ($V_{IS1} > V_{IS2}$) and negative values represent discharge currents ($V_{IS2} > V_{IS1}$). Positive currents above the maximum register value are reported at the maximum value, 0x7FFF. Negative currents below the minimum register value are reported at the minimum value, 0x8000.

Figure 3. **CURRENT REGISTER FORMAT**

DS2755: 12-bit + sign resolution (13-bit), 88ms update interval

MSB—Address 0E

S	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5
MSb							LSb

LSB—Address 0F

2^4	2^3	2^2	2^1	2^0	X	X	X
MSb							LSb

"S": sign bit(s)

Units: 2^0 = 15.625μV/Rsns

Figure 4. **AVERAGE CURRENT REGISTER FORMAT**

DS2755: 15-bit + sign resolution (16-bit), 2.8s update interval

MSB—Address 1A

S	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}
MSb							LSb

LSB—Address 1B

2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
MSb							LSb

"S": sign bit(s)

Units: 2^0 = 1.953μV/Rsns

Current Offset Correction

Continuous offset cancellation is performed automatically to correct for offsets in the current measurement system. Individual values reported by the Current register have a maximum offset of ±0.5 LSb's (±7.8125μV). Individual values reported in the Average Current register have a maximum offset of ±2 LSb's (±7.8125μV).

Current Accumulation

The DS2755 measures current for coulomb counting purposes, with an accuracy of ±2% ±3.9μV over a range of ±64mV. Using a 20mΩ sense resistor, current accumulation is performed over a range of ±3.2A while measuring standby currents with an accuracy of ±195μA. Current measurements are internally summed, or accumulated, with the results displayed in the Accumulated Current Register (ACR). The accuracy of the ACR is dependent on both the current measurement and the accumulation timebase. The 16-bit ACR has a range of ±204.8mVh with an LSb of 6.25μVh. Accumulation of charge current above the maximum register value is reported at the maximum value; conversely, accumulation of discharge current below the minimum register value is reported at the minimum value.

Read and write access is allowed to the ACR. The ACR must be written MSB first then LSB. Whenever the ACR is written, internal fractional accumulation result bits are cleared. In order to preserve the ACR value in case of power loss, the ACR MSB and LSB are automatically backed up to EEPROM after incrementing or decrementing by 100μVh (5.0mAh for Rsns = 20mΩ). The ACR value is recovered from EEPROM on power-up or by a Recall Data command targeting the ACR register address. A write to the ACR results in an automatic copy of the new value to EEPROM.

Figure 5. **ACCUMULATED CURRENT REGISTER FORMAT**

MSB—Address 10

S	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}
MSb							LSb

LSB—Address 11

2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
MSb							LSb

Units: 6.25μVh/Rsns

ACR LSB				
V_{IS1}- V_{IS2}	R_{SNS}			
	20mΩ	15mΩ	10mΩ	5mΩ
6.25□Vh	312.5μAh	416.7μAh	625μAh	1.250mAh

ACR RANGE				
V_{IS1}- V_{IS2}	R_{SNS}			
	20mΩ	15mΩ	10mΩ	5mΩ
±204.8mVh	±10.24Ah	±13.65Ah	±20.48Ah	±40.96Ah

Offset Accumulation Blanking

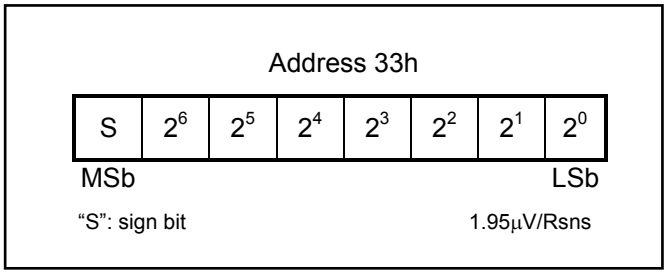
In order to avoid the accumulation of small positive offset errors over long periods, an offset blanking filter is provided. The blanking filter is enabled by setting the OBEN bit in the Status Register. When OBEN is set, charge currents (positive Current register values) less than 62.5μV are not accumulated in the ACR. The minimum charge current accumulated in the ACR is 3.125mA for RSNS=0.020Ω and 12.5mA for RSNS=0.005Ω.

Accumulation Bias

Systematic errors or an application preference can require the application of an arbitrary bias to the current accumulation process. The Accumulation Bias register is provided to allow a user programmed constant positive or negative polarity bias to the current accumulation process. The Accumulation Bias value can be used to estimate battery currents that do not flow through the sense resistor, estimate battery self-discharge, or correct for offset error accumulated in the ACR register. The user programmed two's compliment value in the Accumulation Bias register is added to the ACR once per current sample. The register format supports the accumulation bias to be applied in 1.95μV increments over a ±250μV range. When using a 20mΩ sense resistor, the bias control is 100μA over a ±12.5mA range.

The Accumulation Bias register is directly read and write accessible. The user value is made nonvolatile with a Copy Data command targeting EEPROM block 0. The Accumulation Bias register is loaded from EEPROM memory on power up and a transition from Sleep to Active mode.

Figure 6. **ACCUMULATION BIAS REGISTER FORMAT**



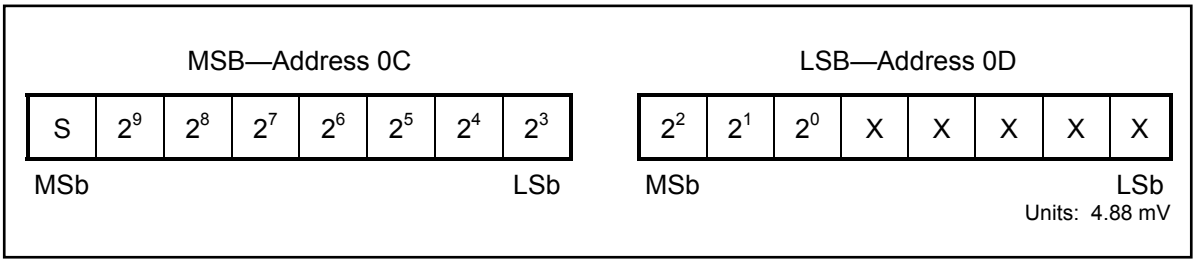
VOLTAGE MEASUREMENT

The voltage register operates in two modes, normal and snapshot. In normal mode, the DS2755 continually measures the voltage between pins V_{IN} and V_{SS} over a 0 to 4.75V range, and the Voltage Register is updated in two's-complement format every 3.4ms with a resolution of 4.88mV.

In snapshot mode, the Voltage register holds the voltage measured immediately following the snapshot trigger. Normal voltage measurements resume after the snapshot value is obtained, however, the SNAP bit must be cleared to re-enable normal mode reporting of voltage measurement to the Voltage register.

Voltages above the maximum register value are reported as the maximum value.

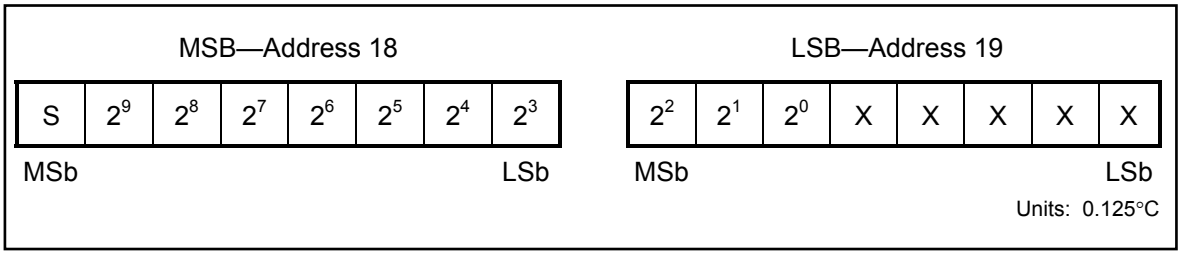
Figure 7. **VOLTAGE REGISTER FORMAT**



TEMPERATURE MEASUREMENT

The DS2755 uses an integrated temperature sensor to continually measure battery temperature. Temperature measurements are updated in the Temperature Register every 220ms in two's-complement format with a resolution of 0.125°C over a ±127°C range. The Temperature Register format is shown in Figure 8.

Figure 8. **TEMPERATURE REGISTER FORMAT**



PROGRAMMABLE I/O

The PIO pin can be used as a general purpose programmable I/O pin, or as an interrupt output to alert the system of a critical change in Temperature or ACR registers. To use the PIO pin in the programmable I/O mode described in this section, the PIO interrupt method must not be enabled. See the Interrupt Signaling section.

As a programmable I/O pin, PIO provides a digital input or an open drain digital output. Writing a 1 to the PIO bit in the Special Feature Register disables the output driver. With the PIO pin Hi-Z, it can be used as an input. The logic level of the PIO pin is reported when the Special Feature Register is read via the serial interface.

To use the PIO pin as an output, write the desired output value to the PIO bit in the Special Feature Register. Writing a 0 to the PIO bit enables the PIO output driver, pulling the PIO pin to V_{SS}. As stated above, writing a 1 to the PIO bit forces the pin to a Hi-Z state. A pullup resistor or current source must be provided to force the pin high. The PIO pin can be biased several volts above V_{DD} allowing inter-operation with a system voltage which is higher than the battery voltage. Consult the Absolute Maximum Ratings table when operating the PIO pin significantly above V_{DD}. The DS2755 turns off the PIO output driver and sets the PIO bit high when in *Sleep* mode or when DQ is low for more than t_{SLEEP}, regardless of the state of the PMOD bit.

INTERRUPT SIGNALING

The interrupt feature is enabled by setting the Interrupt Enable (IE) bit (bit 2 in the Special Feature Register). When IE is set, an interrupt will be signaled if the alarm comparator thresholds are crossed. A 1-Wire RESET clears IE. The host must re-enable interrupts by setting IE in the last transaction on the bus.

The interrupt signal pin is selected by setting or clearing the Interrupt Output Select (IOS) bit (bit 2 in the Status Register). When IOS is set, the DQ pin performs the interrupt signaling, when IOS is cleared, the PIO pin performs the interrupt signaling.

DQ signals an interrupt condition by driving the 1-Wire bus low for t_{IL} µs. The DS2755 and all other 1-Wire devices present on the bus interpret this signal as a 1-Wire RESET. A Presence Pulse should be expected from all 1-Wire devices, including the DS2755 following the interrupt signal. The host system can sense the interrupt signal on the falling or rising edge of either the RESET or Presence Pulse.

PIO signals an interrupt by driving low. PIO remains low until the host clears the condition by writing a 1 to the PIO bit (bit 7 in the Special Feature Register). A pullup resistor or current source must be provided to force the pin high. The host can sense the interrupt on the falling edge of PIO.

ALARM COMPARATORS

Interrupt threshold values can be programmed by the user in the designated SRAM memory registers in the formats and locations found in Figure 9. Since these thresholds are located in SRAM memory, they must be reprogrammed if a loss of power to the DS2755 occurs. The DS2755 interrupts the system host to indicate that one of the following events has occurred:

- Accumulated Current ≥ Current Accumulator Interrupt High Threshold
- Accumulated Current ≤ Current Accumulator Interrupt Low Threshold
- Temperature ≥ Temperature Interrupt High Threshold
- Temperature ≤ Temperature Interrupt Low Threshold

The host may then poll the DS2755 to determine which threshold has been met or exceeded.

Figure 9. **INTERRUPT THRESHOLD REGISTER FORMATS**

Current Accumulator Interrupt High Threshold

MSB—Address 80

S	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}

MSb LSb

LSB—Address 81

2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

MSb LSb

Units: 6.25μVhrs

Current Accumulator Interrupt Low Threshold

MSB—Address 82

S	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}

MSb LSb

LSB—Address 83

2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

MSb LSb

Units: 6.25μVhrs

Temperature Interrupt High Threshold

Address 84

S	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

MSb LSb

Units: 1.0°C

Temperature Alarm Low Threshold

Address 85

S	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

MSb LSb

Units: 1.0°C

SNAPSHOT MODE

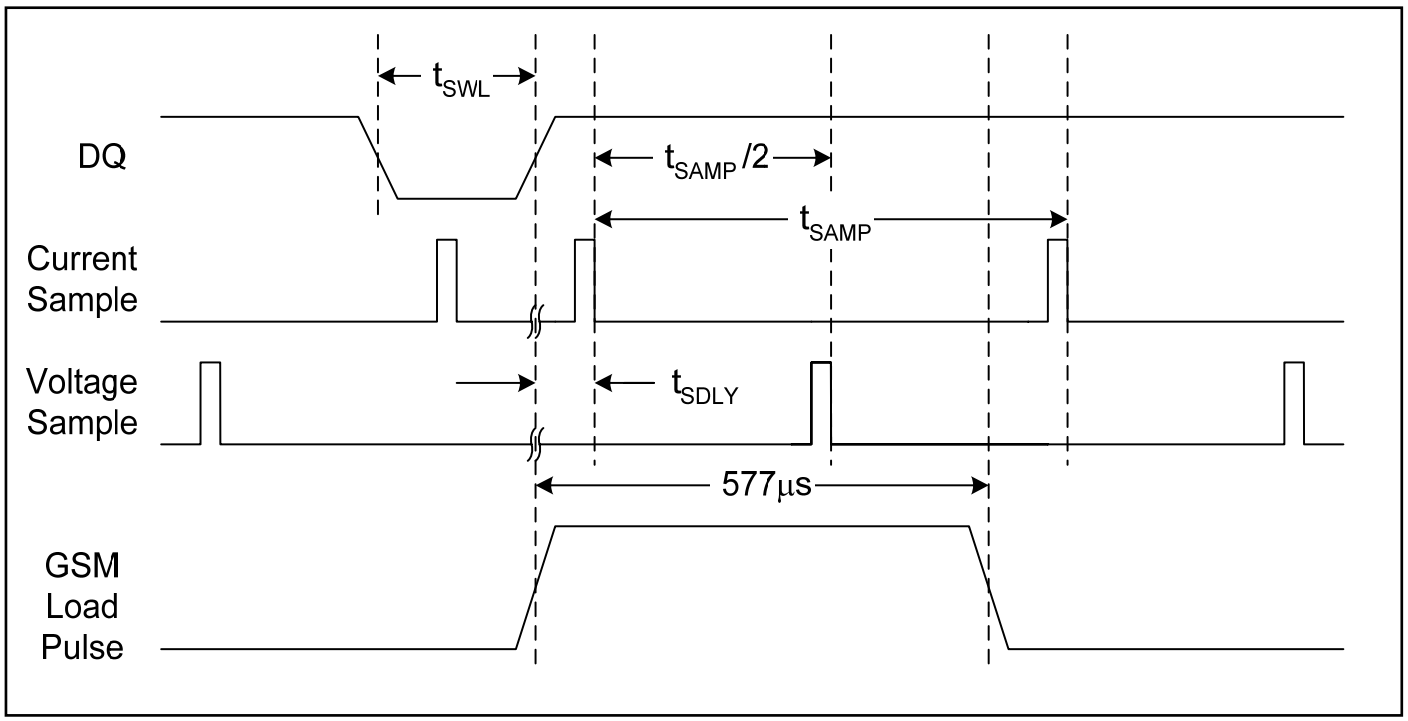
Measurement of the current and voltage can be synchronized to a system event with the Snapshot mode. Triggering a Snapshot event causes the ADC to abandon the current conversion and capture one current and one voltage sample. The Snapshot results are reported in the Current and Voltage registers for retrieval by the host. Normal current, voltage and temperature measurements and current accumulation resume immediately following a Snapshot event, though the Snapshot current and voltage values persist until the host system writes the SNAP bit in the Special Function Register to a 0. Since the snapshot mode disrupts the continuity of the coulomb counting process, it should be used sparingly.

The Sync Function Command [D2h] signals the ADC control to expect a Snapshot trigger on DQ. Following the Sync command, the host can trigger a Snapshot event by toggling the DQ line. Synchronization occurs on the

rising edge of the DQ high to low to high pulse. The Snapshot mode can be abandoned by sending a 1-Wire Reset instead of the synchronization pulse. The rising edge DQ trigger is formed by the first data bit after issuing the Sync Function command. A full byte can be issued, but the rising edge of the first bit sets the trigger point. [[The SNAP bit is set after the rising edge trigger: timing is not critical and could be several 100µs later since it cannot be read quickly via 1-Wire]]. If a 1-wire reset is issued instead of a data bit, then the Snapshot is abandoned (SNAP bit not set).]

The Snapshot Synchronization Timing in Figure 10 illustrates the timing of the Snapshot current and voltage sample apertures relative to the DQ rising edge trigger and one timeslot GSM power amp load pulse. In the diagram, t_{SAMP} = 1/ f_{SAMP}.= 1456^{-1} = 687µs. The current and voltage measurements are taken 343µs apart but within a single GSM timeslot.

Figure 10. **SNAPSHOT SYNCHRONIZATION TIMING**



MEMORY

The DS2755 has a 256-byte linear address space with registers for instrumentation, status, and control in the lower 32 bytes, with lockable EEPROM and SRAM memory occupying portions of the remaining address space. All EEPROM and SRAM memory is general-purpose except addresses 31h and 33h, which should be written with the default values for the Status Register and Accumulation Bias Register, respectively. When the MSB of any two-byte register is read, the MSB and LSB values are latched and held for the duration of the Read Data command. This prevents updates during the read to ensure synchronization between the two register bytes. For consistent results, always read the MSB and the LSB of a two-byte register during the same Read Data command sequence. In describing register control and status bits, the terms set and clear refer to internal operations which manipulate bit values. The terms read and write refer to 1-Wire access to the bit values. Several bits are set internally but require the host system to write them to a 0 value.

EEPROM memory is shadowed by RAM to eliminate programming delays between writes and to allow the data to be verified by the host system before being copied to EEPROM. The Read Data and Write Data protocols to/from EEPROM memory addresses access the shadow RAM. The Recall Data function command transfers data from the EEPROM to the shadow RAM. The Copy Data function command transfers data from the shadow RAM to the EEPROM and requires t_{EEC} to complete programming of the EEPROM cells. In unlocked EEPROM blocks, writing data updates shadow RAM. In locked EEPROM blocks, the Write Data command is ignored. The Copy Data function command copies the contents of shadow RAM to EEPROM in an unlocked block of EEPROM but has no effect on locked blocks. The Recall Data function command copies the contents of a block of EEPROM to shadow RAM regardless of whether the block is locked or not.

Figure 9. EEPROM Access via Shadow RAM

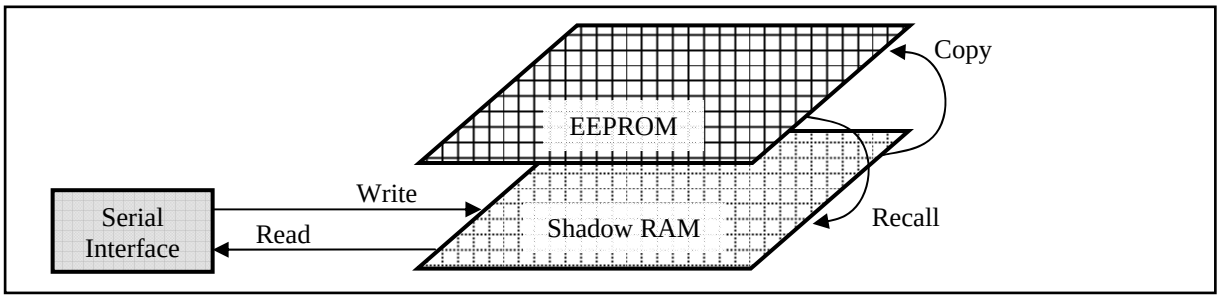


Table 1. MEMORY MAP

ADDRESS (HEX)	DESCRIPTION	READ/WRITE
00	Reserved	
01	Status Register	R
02 to 06	Reserved	
07	EEPROM Register	R/W
08	Special Feature Register	R/W
09 to 0B	Reserved	
0C	Voltage Register MSB	R
0D	Voltage Register LSB	R
0E	Current Register MSB	R
0F	Current Register LSB	R
10	Accumulated Current Register MSB	R/W
11	Accumulated Current Register LSB	R/W
12 to 17	Reserved	
18	Temperature Register MSB	R
19	Temperature Register LSB	R
1A	Average Current Register MSB	R
1B	Average Current Register LSB	R
1C to 1F	Reserved	
20 to 3F	EEPROM, block 0	R/W*
40 to 5F	EEPROM, block 1	R/W*
60 to 7F	EEPROM, block 2	R/W*
80 to 8F	SRAM	R/W
90 to FF	Reserved	

**Each EEPROM block is read/write until locked by the LOCK command, after which it is read-only.*

STATUS REGISTER

The default values for the Status Register bits are stored in lockable EEPROM in the corresponding bits of address 31h. A Recall Data command for EEPROM block 1 recalls the default values into the Status Register bits. The format of the Status Register is shown in Figure 11. The function of each bit is described in detail in the following paragraphs.

Figure 11. **STATUS REGISTER FORMAT**

Address 01

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
X	X	PMOD	RNAOP	UVEN	IOS	OBEN	OVD

PMOD—*Sleep* Mode Enable. A value of 1 in this bit enables the DS2755 to enter sleep mode when the DQ line goes low for greater than t_{SLEEP}. A value of 0 disables the DS2755 from entering the sleep mode. This bit is read-only. The desired default value should be set in bit 5 of address 31h. The factory default is 0.

RNAOP—Read Net Address Opcode. A value of 0 in this bit sets the opcode for the Read Net Address command to 33h, while a 1 sets the opcode to 39h. This bit is read-only. The desired default value should be set in bit 4 of address 31h. The factory default is 0.

UVEN—Undervoltage *Sleep* Enable. A value of 1 in UVEN along with a value of 1 in PMOD enables the DS2755 to enter sleep mode when the voltage on V_{IN} drops below undervoltage threshold V_{UV} for t_{UVD} (cell depletion). A value of 0 disables the DS2755 from entering the sleep mode due to undervoltage events. This bit is read-only. The desired default value should be set in bit 3 of address 31h. The factory default is 0.

IOS—Interrupt output select. IOS set to a 1 selects the DQ interrupt signaling method. IOS cleared to 0 selects the PIO interrupt signaling method. The IE bit must be set to enable either type of interrupt. The desired default value should be set in bit 2 of address 31h. The factory default is 0.

OBEN—Offset Blanking Enable. A value of 1 in this bit location enables the offset blanking function described in the Current Accumulation section. If set to 0, the offset blanking function is disabled. This bit is read-only. The desired default value should be set in bit 1 of address 31h. The factory default is 0.

OVD—Overdrive Timing Enable. A value of 1 in this bit location enables the Overdrive 1-Wire timings. If set to 0, the Regular mode timings are enabled. This bit cannot be written directly. The desired bit value must be written to bit 1 of address 31h, (an EEPROM block 0 location), then recalled before any change to the 1-Wire speed becomes effective. A power-on reset forces a recall of settings from EEPROM block 0. The factory default in bit 1 of address 31h is 0 (Standard 1-Wire timing).

X—Reserved Bits.

EEPROM REGISTER

The format of the EEPROM Register is shown in Figure 12. The function of each bit is described in detail in the following paragraphs.

Figure 12. **EEPROM REGISTER FORMAT**

Address 07

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
EEC	LOCK	X	X	X	BL2	BL1	BL0

EEC—EEPROM Copy Flag. A 1 in this read-only bit indicates that a Copy Data command is in progress. While this bit is high, writes to EEPROM addresses are ignored. A 0 in this bit indicates that data can be written to unlocked EEPROM blocks.

LOCK—EEPROM Lock Enable. When this bit is 0, the Lock command is ignored. Writing a 1 to this bit enables the Lock command. After the Lock command is executed, the LOCK bit is reset to 0. The factory default is 0.

BL2—EEPROM Block 2 Lock Flag. A 1 in this read-only bit indicates that EEPROM block 2 (addresses 60 to 7F) is locked (read-only), while a 0 indicates block 1 is unlocked (read/write).

BL1—EEPROM Block 1 Lock Flag. A 1 in this read-only bit indicates that EEPROM block 1 (addresses 40 to 5F) is locked (read-only), while a 0 indicates block 1 is unlocked (read/write).

BL0—EEPROM Block 0 Lock Flag. A 1 in this read-only bit indicates that EEPROM block 0 (addresses 20 to 3F) is locked (read-only), while a 0 indicates block 0 is unlocked (read/write).

X—Reserved Bits.

SPECIAL FEATURE REGISTER

The format of the Special Feature Register is shown in Figure 13. The function of each bit is described in detail in the following paragraphs.

Figure 13. SPECIAL FEATURE REGISTER FORMAT

Address 08

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
POR	PIO	X	X	X	IE	X	SNAP

POR—POR Indicator bit. This bit is set to a 1 when the DS2755 experiences a power-on-reset (POR) event. To use the POR bit to detect a power-on-reset, the POR bit must be set to a 0 by the host system upon power-up and after each subsequent occurrence of a POR. This bit is read/write to 0.

PIO—PIO Pin Sense and Control. See the *Programmable I/O* section for details on this read/write bit.

IE—Interrupt Enable. A value of 1 in this bit location enables interrupt signaling to the host system. If set to 0, the interrupt signaling is disabled. When IE is 0, the alarm comparator registers are available as SRAM and have no effect on device operation. IE bit is read/write to 1. It is cleared to 0 by a 1-Wire reset.

SNAP—Snapshot Control. This bit is set to a 1 immediately after the DS2755 executes a Snapshot conversion pair. SNAP = 1 indicates that the Current and Voltage registers contain Snapshot results. While SNAP = 1, the Snapshot results persist in the Current and Voltage registers until the SNAP bit is written to a 0 by the host system. This bit is read/write to 0.

X—Reserved Bits.

1-WIRE BUS SYSTEM

The 1-Wire bus is a system that has a single bus master and one or more slaves. A multidrop bus is a 1-Wire bus with multiple slaves. A single-drop bus has only one slave device. In all instances, the DS2755 is a slave device. The bus master is typically a microprocessor in the host system. The discussion of this bus system consists of four topics: 64-Bit Net Address, Hardware Configuration, Transaction Sequence, and 1-Wire Signaling.

64-BIT NET ADDRESS

Each DS2755 has a unique, factory-programmed 1-Wire net address that is 64 bits in length. The first 8 bits are the 1-Wire family code (35h for DS2755). The next 48 bits are a unique serial number. The last 8 bits are a CRC of the first 56 bits (see Figure 14). The 64-bit net address and the 1-Wire I/O circuitry built into the device enable the DS2755 to communicate through the 1-Wire protocol detailed in the 1-Wire Bus System section of this data sheet.

Figure 14. 1-WIRE NET ADDRESS FORMAT

8-Bit CRC	48-Bit Serial Number	8-Bit Family Code (35h)

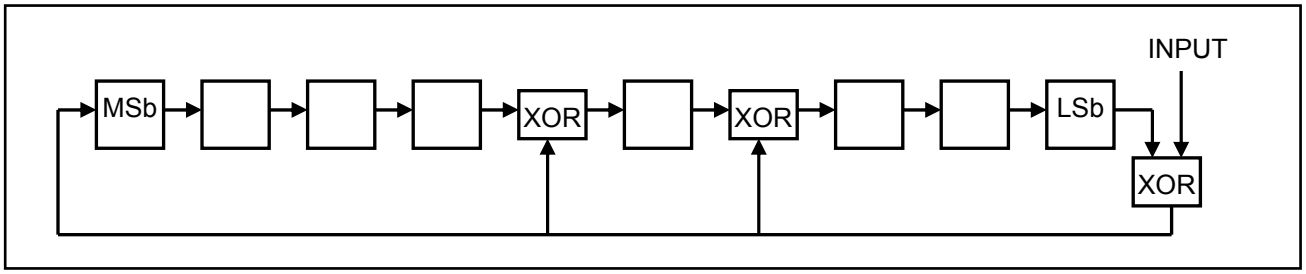
MSb LSb

CRC GENERATION

The DS2755 has an 8-bit CRC stored in the most significant byte of its 1-Wire net address. To ensure error-free transmission of the address, the host system can compute a CRC value from the first 56 bits of the address and compare it to the CRC from the DS2755. The host system is responsible for verifying the CRC value and taking action as a result. The DS2755 does not compare CRC values and does not prevent a command sequence from proceeding as a result of a CRC mismatch. Proper use of the CRC can result in a communication channel with a very high level of integrity.

The CRC can be generated by the host using a circuit consisting of a Shift Register and XOR gates as shown in Figure 15, or it can be generated in software. Additional information about the Dallas 1-Wire CRC is available in Application Note 27: *Understanding and Using Cyclic Redundancy Checks with Dallas Semiconductor Touch Memory Products*.

Figure 15. **1-WIRE CRC GENERATION BLOCK DIAGRAM**



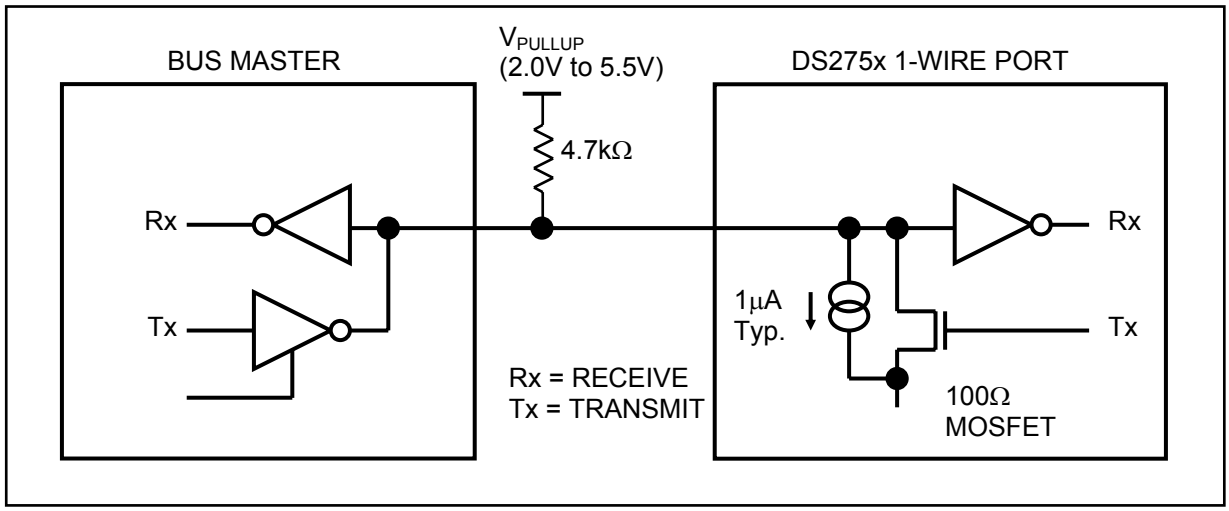
In the circuit in Figure 15, the shift bits are initialized to 0. Then, starting with the least significant bit of the family code, one bit at a time is shifted in. After the 8th bit of the family code has been entered, then the serial number is entered. After the 48th bit of the serial number has been entered, the Shift Register contains the CRC value.

HARDWARE CONFIGURATION

Because the 1-Wire bus has only a single line, it is important that each device on the bus be able to drive it at the appropriate time. To facilitate this, each device attached to the 1-Wire bus must connect to the bus with open-drain or tri-state output drivers. The DS2755 uses an open-drain output driver as part of the bidirectional interface circuitry shown in Figure 16. If a bidirectional pin is not available on the bus master, separate output, and input pins can be connected together.

The 1-Wire bus must have a pullup resistor at the bus-master end of the bus. For short line lengths, the value of this resistor should be approximately 5kΩ. The idle state for the 1-Wire bus is high. If, for any reason, a bus transaction must be suspended, the bus must be left in the idle state in order to properly resume the transaction later. If the bus is left low for more than 120μs, slave devices on the bus begin to interpret the low period as a reset pulse, effectively terminating the transaction.

Figure 16. **1-WIRE BUS INTERFACE CIRCUITRY**



TRANSACTION SEQUENCE

The protocol for accessing the DS2755 through the 1-Wire port is as follows:

- Initialization
- Net Address Command
- Function Command
- Transaction/Data

The sections that follow describe each of these steps in detail.

All transactions of the 1-Wire bus begin with an initialization sequence consisting of a reset pulse transmitted by the bus master followed by a presence pulse simultaneously transmitted by the DS2755 and any other slaves on the bus. The presence pulse tells the bus master that one or more devices are on the bus and ready to operate. For more details, see the *I/O Signaling* section.

NET ADDRESS COMMANDS

Once the bus master has detected the presence of one or more slaves, it can issue one of the net address commands described in the following paragraphs. The name of each command is followed by the 8-bit opcode for that command in square brackets. Figure 17 presents a transaction flowchart of the net address commands.

Read Net Address [33h or 39h]. This command allows the bus master to read the DS2755's 1-Wire net address. This command can only be used if there is a single slave on the bus. If more than one slave is present, a data collision occurs when all slaves try to transmit at the same time (open drain produces a wired-AND result). The RNAOP bit in the Status Register selects the opcode for this command, with RNAOP = 0 indicating 33h and RNAOP = 1 indicating 39h.

Match Net Address [55h]. This command allows the bus master to specifically address one DS2755 on the 1-Wire bus. Only the addressed DS2755 responds to any subsequent function command. All other slave devices ignore the function command and wait for a reset pulse. This command can be used with one or more slave devices on the bus.

Skip Net Address [CCh]. This command saves time when there is only one DS2755 on the bus by allowing the bus master to issue a function command without specifying the address of the slave. If more than one slave device is present on the bus, a subsequent function command can cause a data collision when all slaves transmit data at the same time.

Search Net Address [F0h]. This command allows the bus master to use a process of elimination to identify the 1-Wire net addresses of all slave devices on the bus. The search process involves the repetition of a simple three-step routine: read a bit, read the complement of the bit, then write the desired value of that bit. The bus master performs this simple three-step routine on each bit location of the net address. After one complete pass through all 64 bits, the bus master knows the address of one device. The remaining devices can then be identified on additional iterations of the process. See Chapter 5 of the *Book of DS19xx iButton® Standards* for a comprehensive discussion of a net address search, including an actual example. This publication can be found on the Maxim/Dallas website at www.maxim-ic.com.

FUNCTION COMMANDS

After successfully completing one of the net address commands, the bus master can access the features of the DS2755 with any of the function commands described in the following paragraphs. The name of each function is followed by the 8-bit opcode for that command in square brackets.

Read Data [69h, XX]. This command reads data from the DS2755 starting at memory address XX. The LSb of the data in address XX is available to be read immediately after the MSb of the address has been entered. Because the address is automatically incremented after the MSb of each byte is received, the LSb of the data at address XX + 1 is available to be read immediately after the MSb of the data at address XX. If the bus master continues to read beyond address FFh, the DS2755 outputs logic 1 until a reset pulse occurs. Addresses labeled "reserved" in the memory map contain undefined data. The Read Data command can be terminated by the bus master with a reset pulse at any bit boundary.

Write Data [6Ch, XX]. This command writes data to the DS2755 starting at memory address XX. The LSb of the data to be stored at address XX can be written immediately after the MSb of the address has been entered. Because the address is automatically incremented after the MSb of each byte is written, the LSb to be stored at address XX + 1 can be written immediately after the MSb to be stored at address XX. If the bus master continues to write beyond address FFh, the DS2755 ignores the data. Writes to read-only addresses, reserved addresses and locked EEPROM blocks are ignored. Incomplete bytes are not written. Writes to unlocked EEPROM blocks are to shadow RAM rather than EEPROM. See the *Memory* section for more details.

Copy Data [48h, XX]. This command copies the contents of shadow RAM to EEPROM for the 32-byte EEPROM block containing address XX. Copy Data commands that address locked blocks are ignored. While the Copy Data command is executing, the EEC bit in the EEPROM Register is set to 1 and writes to EEPROM addresses are ignored. Reads and writes to non-EEPROM addresses can still occur while the copy is in progress. The Copy Data command execution time, t_{EEC}, is 2ms typical and starts after the last address bit is transmitted.

Recall Data [B8h, XX]. This command recalls the contents of the 32-byte EEPROM block containing address XX to shadow RAM.

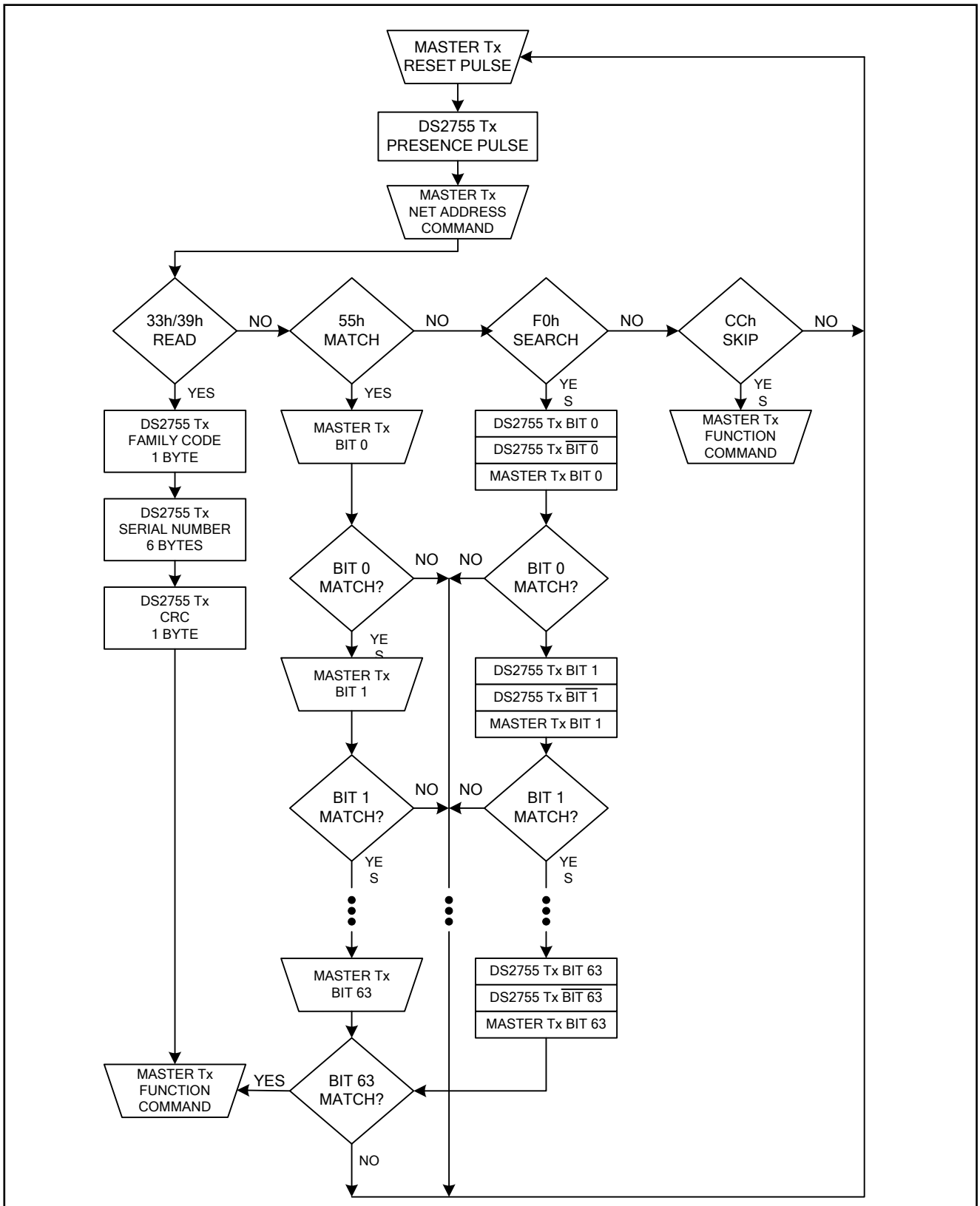
Lock [6Ah, XX]. This command locks (write-protects) the 32-byte block of EEPROM memory containing memory address XX. The LOCK bit in the EEPROM Register must be set to l before the Lock command is executed. If the LOCK bit is 0, the Lock command has no effect. The Lock command is permanent; a locked block can never be written again.

Sync [D2h, XX]. This command allows the bus to be used to trigger current and voltage Snapshot readings. Following the issue of the Sync command, the bus returns to the idle state awaiting the measurement trigger. When the bus transitions high to low and then low to high on the first data bit issued after the command byte, the Snapshot measurements are performed. Only one bit of the data byte is required to trigger the Snapshot measurements. One Snapshot command must be issued for each Snapshot trigger event.

Table 2. FUNCTION COMMANDS

COMMAND	DESCRIPTION	COMMAND PROTOCOL	BUS STATE AFTER COMMAND PROTOCOL	BUS DATA
Read Data	Reads data from memory starting at address XX	69h, XX	Master Rx	Up to 256 bytes of data
Write Data	Writes data to memory starting at address XX	6Ch, XX	Master Tx	Up to 256 bytes of data
Copy Data	Copies shadow RAM data to EEPROM block containing address XX	48h, XX	Bus idle	None
Recall Data	Recalls EEPROM block containing address XX to shadow RAM	B8h, XX	Bus idle	None
Lock	Permanently locks the block of EEPROM containing address XX	6Ah, XX	Bus idle	None
Sync	Arms the Snapshot Measurement Mode	D2h, XX	Bus idle	None

Figure 17. **NET ADDRESS COMMAND FLOW CHART**



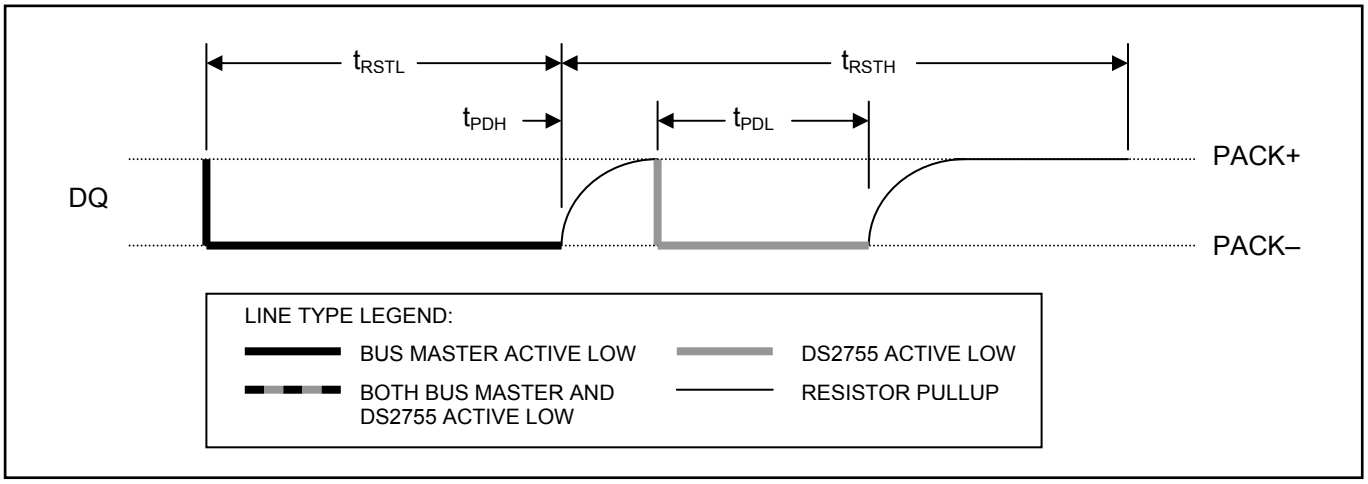
I/O SIGNALING

The 1-Wire bus requires strict signaling protocols to ensure data integrity. The four protocols or signaling types used are:

1) Initialization sequence (Reset Pulse followed by Presence Pulse)
2) Write 0
3) Write 1
4) Read Data

All signaling is initiated by the bus master. Except for the Presence Pulse, all falling edges are created by the bus master. The initialization sequence required to begin communication with the DS2755 is shown in Figure 18. A presence pulse following a reset pulse indicates the DS2755 is ready to accept a net address command. The bus master transmits (Tx) a reset pulse for t_{RSTL}. The bus master then releases the line and goes into receive mode (Rx). The 1-Wire bus line is then pulled high by the pullup resistor. After detecting the rising edge on the DQ pin, the DS2755 waits for t_{PDH} and then transmits the Presence Pulse for t_{PDL}.

Figure 18. **1-WIRE INITIALIZATION SEQUENCE**



WRITE-TIME SLOTS

A write-time slot is initiated when the bus master pulls the 1-Wire bus from a logic-high (inactive) level to a logic-low level. There are two types of write-time slots: write 1 and write 0. All write-time slots must be t_{SLOT} in duration with a 1μs minimum recovery time, t_{REC}, between cycles.

The bus master generates a write 1 time slot by pulling 1-Wire bus line low for t_{LOW1} and then releasing it. The bus must be pulled high within 15μs in Standard mode or 2μs in Overdrive mode after the start of the write-time slot. The bus master generates a write 0 time slot by pulling 1-Wire bus line low and then holding it low for t_{LOW0}, or up to the end of the write-time slot.

The DS2755 samples the 1-Wire bus after the line falls, sampling occurs between 15μs and 60μs in Standard mode and between 2μs and 6μs in Overdrive mode. If the line is high when sampled by the DS2755, a write 1 occurs, that is, the DS2755 accepts the bit value to be a 1. If the line is low when sampled, a write 0 occurs, that is, the DS2755 accepts the bit value to be a 0. See Figure 19 for more information.

READ-TIME SLOTS

A read-time slot is initiated when the bus master pulls the 1-Wire bus line from a logic-high level to a logic-low level. The bus master generated read-time slot results in a read 1 and read 0 depending on the data presented by the DS2755. All read-time slots must be t_{SLOT} in duration with a 1μs minimum recovery time, t_{REC}, between cycles.

The bus master initiates a read-time slot by pulling the bus line low for at least 1μs and then releasing it to allow the DS2755 to present valid data. The DS2755 generates a read 0 by holding the line low. The line is held low for at least the Read Data Valid time (t_{RDV}) from the start of the read-time slot. The DS2755 releases the bus line and allows it to be pulled high by the external pullup resistor some time after t_{RDV} but before the end of the read-time slot. A read 1 is generated by not holding the line low after the time slot is initiated by the master. The line is allowing it to be pulled high as soon as it is released by the master. The bus master must sample the bus after initializing the time slot and before t_{RDV} to read the data value transmitted by the DS2755. Sampling should occur

as close to t_{RDV} as possible to allow for the rise time of the passive pullup 1-Wire bus. See Figure 19 for more information.

Figure 19. **1-WIRE WRITE AND READ TIME SLOTS**