HYCON TECHNOLOGY

HY4222
Datasheet

1-to-3 Cell Li Metal Battery Gauge IC

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1. General Description

The HY4222 operates with 1-to-3 Li Metal battery cell as a stand–along battery gauge. Minimum firmware development support is required from system. The device uses GaugePack™ algorithm, which mixes Coulomb–Counting and Open–Circuit–Voltage (OCV) measurements with battery cell characteristics to manage battery gauge, to maintain accurate battery capacity estimates with compensation for age and self–discharge effects. The device provides voltage, current and thermal protection alerts, and also provides nonvolatile Flash memory for user purpose. The measured, estimated data set, and specific application information on the device are accessible via a proprietary 2–Wire (I^2C) interface.

2. Features

- Used as Stand–alone Battery Gauge for 1-to-3 Li Metal Cell Battery Applications
  - Provide 1 to 3 Cell Series Options
  - Integrate Dual 16–Bit ADCs for Precision Voltage, Current, and Temperature Measurements
  - Use a Low Cost and Low Value Sense Resistor with Calibration for Current Measurement
  - Use Integrated and External Temperature Sensors for Temperature Measurement
- Integrate Accurate Battery Capacity Estimate System
  - Integrate GaugePack™ Algorithm – Mixed Algorithm with Coulomb Counting, Open Circuit Cell Voltage Measurement and Cell Characteristics
  - Compensate Age and Self–Discharge Effects Automatically
  - Require No Fully Battery Charge-to-Discharge or Discharge-to-Charge Recycling for Capacity Learning Process
  - Backup Specific Battery Capacity Information to Nonvolatile (NV) Flash Memory Automatically
- Feature Programmable Protection Alerts
  - Protections for Voltage, Current, and Temperature Faults
  - Provide Pin Alert Indication for Temperature
- Backup Battery Lifetime Data to Nonvolatile (NV) Flash Memory Automatically
- Provide 96 Bytes Nonvolatile (NV) User Scratch Pad Flash Memory
- Support Low Power Modes Management
- Support 2–Wire (I^2C) Communication Interface
- Support LEDs for Capacity Indication

- Tiny, RoSH–free / Pb–free, 4.4mm x 6.5mm 20–pin TSSOP Package

3. Applications

- E-Bikes
- E-Power Tools
- Portable Instruments

4. Ordering Information

Device No.[1]	Package Type	Pins	Package Drawing		Code[2]	Material Composition	MSL[3]
HY4222-T020	TSSOP	20	T	020	-	Green[4]	MSL-3

1 Device No – Package Type Description

Ex: You request blank code in DFN14 package for HY4141. The device No. will be HY4141-C014

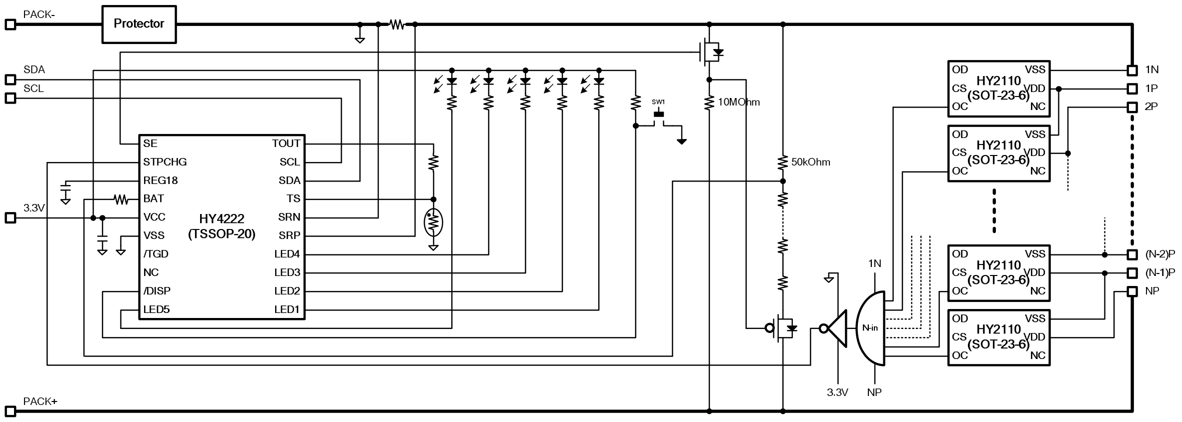
3 MSL:

The Moisture Sensitivity Level ranking conforms to IPC/JEDEC J-STD-020 industry standard categorization. The products are processed, packed, transported and used with reference to IPC/JEDEC J-STD-033.

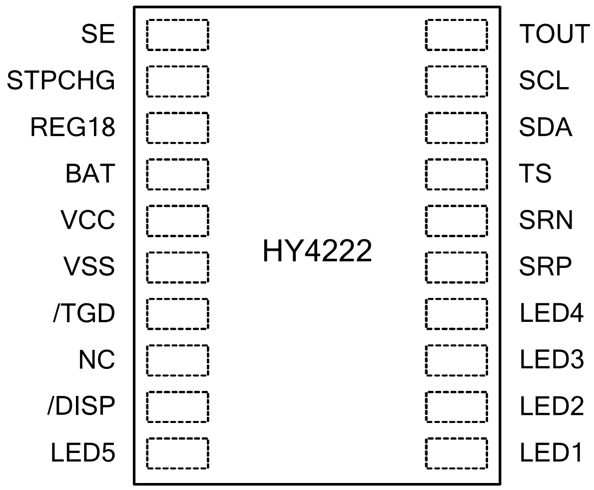
4 Green (RoHS & no Cl/Br):

HYCON products are Green products that compliant with RoHS directive and are Halogen free (Br/Cl<0.1%)

5. Application Circuit



6. Pin Configuration



4.4mm x 6.5mm TSSOP - 20

7. Pin Definition

PIN	TYPE[(1)]	NAME	DESCRIPTION
1	O	SE	**Shutdown Enable Indication Output.** Used to indicate the device in Hibernate mode. A push-pull output. Active high.
2	I	STPCHG	**Stop Charge Input.** Used to indicate the fully charge termination. Active high.
3	OA	REG18	**1.8V Regulated Power Output.** A 1.8V regulated voltage output. Only for device use. Connect a 1uF ceramic capacitor to VSS.
4	IA	BAT	**Battery Voltage Sense Input.** Used to measure battery voltage. Connect to battery positive terminal.
5	OA	VCC	**Regulated Power Supply.** A 3.3V regulated voltage output. Only for device use. Connect a 1uF ceramic capacitor to VSS.
6	P	VSS	**Device Ground.**
7	IA	/TGD	**Temperature Good Indication Output.** Used to indicate no temperature fault when configured. A push-pull output. Active low.
8		NC	**No Connection.**
9	I	/DISP	**LED Display Control Input.** Connect to VSS via the button.
10	IA	LED5	**LED Display Input 5.** Used to indicate a ration of battery capacity. Active low.
11	IA	LED1	**LED Display Input 1.** Used to indicate a ration of battery capacity. Active low.
12	IA	LED2	**LED Display Input 2.** Used to indicate a ration of battery capacity. Active low.
13	IA	LED3	**LED Display Input 3.** Used to indicate a ration of battery capacity. Active low.
14	IA	LED4	**LED Display Input 4.** Used to indicate a ration of battery capacity when configured. Active low.
15	IA	SRP	**Current Sense Positive Input.** Connect to a 5mΩ to 20mΩ current sense resistor. Connect near to battery negative terminal.
16	IA	SRN	**Current Sense Negative Input.** Connect to a 5mΩ to 20mΩ current sense resistor. Connect near to VSS.
17	IA	TS	**Thermistor Sense Input.**

PIN	TYPE(1)	NAME	DESCRIPTION
			Used to measure temperature in battery pack. Connect to a thermistor.
18	I/OD	SDA	**Serial Data Input/Output.** Slave I^2C communication data line. Open–drain output. Use with an external 10kΩ pull–up resister.
19	I	SCL	**Serial Clock Input.** Slave I^2C communication clock line. Use with an external 10kΩ pull–up resister.
20	OA	TOUT	**Power Output to Thermistor Network.** Connect to a pull-up resistor that connects a thermistor to VSS.

NOTE: (1) I = DIGITAL INPUT; O = DIGITAL OUTPUT; OD = OPEN-DRAIN OUTPUT; IA = ANALOG INPUT; OA = ANALOG OUTPUT; P = POWER CONNECTION.

8. Function Outline

The HY4222 functions as an accurate battery gauge for a battery pack using 1-to-3 Li Metal cell. The device provides accurate estimates of capacity information and timely voltage, temperature and current measurements. Minimum firmware development support is required from system.

The proprietary GaugePack^{TM} mixing Coulomb Counting and Open Circuit Cell Voltage (OCV) related algorithms estimates battery capacity to be the key to support battery information, such as State–Of–Charge (SOC), based on battery cell characteristics. With compensation for age and self–discharge effects exercised, the performance of battery gauge is well improved. The configurable capacity learning process does not require any fully charge-to-discharge or discharge-to-charge battery cycling, and offers best opportunity to update status of battery capacity. The critical capacity information is periodically backed up into the integrated Flash memory in case of loss of power. The HY4222 supports four LEDs to indicate battery capacity in configurable settings.

The HY4222 integrates two sets of precision 16–bit delta-sigma ADCs for voltage, temperature, and current measurements. The performance of measurements is optimized with appropriate calibrations and compensations during manufacturing and normal operation. The current is measured across a low costly, small value sense resistor (1mΩ to 4mΩ typically) located between battery and package terminals. The temperature can be measured from the integrated temperature sensor and the external thermistor network powered and controlled by the device. Users can specify characteristics of NTC thermistor in Flash memory.

The HY4222 features protection alerts for voltage, current and temperature faults during operation. The related thresholds and delays can be configured in user programmable Flash memory. A specific pin is assigned to indicate the temperature alert, and can be used to control external components.

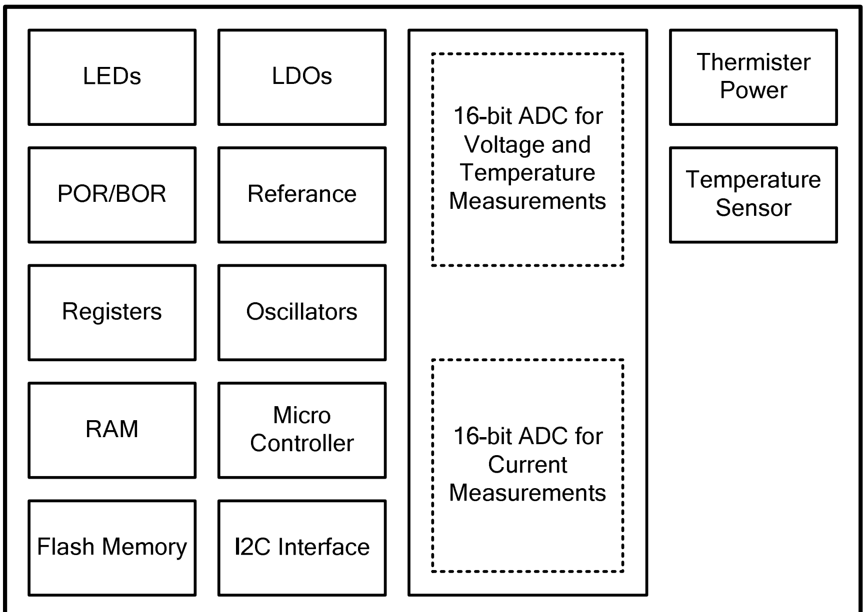
Battery cell and application information is stored in non-volatile Flash memory. Many of these Flash memory locations are accessible during application development. They can not be accessed directly during end–equipment operation. Access to these memory locations is achieved through individual commands, a sequence of data–flash–access commands, or use of the companion evaluation software.

The HY4222 provides 96 bytes of user programmable Flash memory, partitioned into three 32–byte blocks: Manufacturer Info Block A, Manufacturer Info Block B, and Manufacturer Info Block C. This data space is accessed through a Data Flash interface.

The HY4222 uses a proprietary 2–Wire (I^2C) communication interface, and executes commands. The measured, estimated data set, protection alerts, and specific application information are accessed through a series of commands, called *Standard Commands*. Further capability is provided by *Extended Commands*. These commands are used to read and write information contained within the HY4222 control and status registers, as well as the Flash memory locations. The 7–bit address 1011000 is assigned to the HY4222.

The HY4222 offers four power modes: NORMAL, SLEEP, FULLSLEEP, and HIBERNATE, to minimize power consumption and transits between modes automatically with appropriate configurable settings and communication events. Some of these modes can be initiated through commands.

9. Block Diagram



HY4220 Block Diagram

10. Electrical Characteristics

ABSOLUTE MAXIMUM RATINGS

Voltage on BAT pins relative to VSS	–0.3V to 16V
Voltage on REG18, VCC pins relative to VSS	–0.3V to 3.6V
Voltage on SRP, SRN, TS, TOUT, STPCHG pins relative to VSS	–0.3V to VCC + 0.3V
Voltage on SDA, SCL, SE, /TGD, LED5, LED4, LED3, LED2, LED1 pins relative to VSS	–0.3V to 6.0V
Functional Temperature Range	–40℃ to +100℃
Storage Temperature Range	–65℃ to +150℃
Soldering Temperature (10 Sec)	+260℃

* *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.*

ELECTRCAL CHARACTERISTICS

(V_{CC} = 3.3V. V_{BAT} = 2.45V to 5.5V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage	V_{CC}	Normal operation.	3.0	3.3	3.6	V
		No Flash writes.	2.45		3.0	
Supply Current	I_{CC}	NORMAL Mode. (Note 1) $I_{LOAD} > I_{SLEEP}$		130		µA
	I_{SLP}	SLEEP Mode. $I_{LOAD} \leq I_{SLEEP}$		60		
	$I_{FULLSLP}$	FULLSLEEP Mode. $I_{LOAD} \leq I_{SLEEP}$		20		
	I_{HIB}	HIBERNATE Mode. $I_{LOAD} \leq I_{HIBERNATE}$		6		
Power–Up Communication Delay	t_{PUCD}			350		ms
TOUT, SDA, SE Output Logic Low	V_{OL}	I_{OL} = 3mA			0.4	V
TOUT Output Logic High	$V_{OH(PP)}$	I_{OH} = –1mA	V_{CC} – 0.5			V
SDA, SE Output Logic High	$V_{OH(OD)}$	External pull–up resisters to VCC. I_{OH} = –3mA	V_{CC} – 0.5			V

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage	V_{CC}	Normal operation.	3.0	3.3	3.6	V
		No Flash writes.	2.45		3.0	
SDA, SCL, STPCHG Input Logic Low	V_{IL}		–0.3		0.6	V
SDA, SCL STPCHG Input Logic High	$V_{IH(OD)}$		1.2		V_{CC}	V
BAT Input Voltage Range			V_{SS} – 0.125		V_{SS} + 5.5	V
SRP, SRN Input Voltage Range			V_{SS} – 0.25		V_{SS} + 0.25	V
TS Input Voltage Range			V_{SS} – 0.125		V_{CC} – 0.1	V

POWER–ON RESET

(V_{CC} = 3.3V. V_{BAT} = 2.45V to 5.5V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Power–On–Reset Voltage	V_{POR}	Rising–edge voltage at VCC.	2.05	2.20	2.30	V
Hysteresis Voltage	V_{POR_HYS}		45	115	185	mV

1.8V LDO REGULATOR

(V_{CC} = 3.3V. V_{BAT} = 2.45V to 5.5V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Regulator Output Voltage, REG18	V_{REG}	2.7V ≤ V_{CC} I_{REG18} ≤ 16mA	–40°C to +85°C	1.70	1.80	1.90	V
		2.45V ≤ V_{CC} ≤ 2.7V I_{REG18} ≤ 3mA		1.65			
Regulator Dropout Voltage	V_{DO}	V_{CC} = 2.7V I_{REG_OUT} ≤ 16mA	–40°C to +85°C			280	mV
		V_{CC} = 2.45V I_{REG18} ≤ 3mA				50	
Short Circuit Current Limit	I_{SHORT_REG18}	V_{REG18} = 0V	–40°C to +85°C			250	mA

THERMISTOR DRIVE CHARACTERISTICS

(V_{CC} = 3.3V. V_{BAT} = 2.45V to 5.5V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	V_{TOUT}	I_{TOUT} = 0		V_{CC}		V
TOUT Pass Element Resistance	$R_{DS,ON}$	I_{TOUT} = 1mA		50	100	Ω

ULTRA HIGH FREQUENCY OSCILLATOR CHARACTERISTICS

(V_{CC} = 3.3V. V_{BAT} = 2.45V to 5.5V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Frequency	f_{OSC}			8		MHz
Startup Delay	t_{SXO}			2.5	5	ms

HIGH FREQUENCY OSCILLATOR CHARACTERISTICS

(V_{CC} = 3.3V. V_{BAT} = 2.45V to 5.5V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Frequency	f_{OSC}			2		MHz
Startup Delay	t_{SXO}			2.5	5	ms

LOW FREQUENCY OSCILLATOR CHARACTERISTICS

(V_{CC} = 3.3V. V_{BAT} = 2.45V to 5.5V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Frequency	f_{OSC}			32.768		KHz
Frequency Error	f_{EIO}	0 ≤ Ta ≤ 60ºC	–1.5	0.25	1.5	%
		–20ºC ≤ Ta ≤ 70ºC	–2.5	0.25	2.5	
		–40ºC ≤ Ta ≤ 85ºC	–4.0	0.25	4.0	
Startup Delay	t_{SXO}				500	µs

INTEGRATING ADC (COULOMB COUNTER) CHARACTERISTICS

(V_{CC} = 3.3V. V_{BAT} = 2.45V to 5.5V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input voltage Range (V_{SRN} and V_{SRP})	$V_{SR,IN}$	$V_{SR} = V_{SRP} - V_{SRN}$	–0.25		0.25	V

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Conversion Time	t_{SXO}	Single conversion		1		s
Resolution		Single conversion	15		16	bits
Full Scale Error	$V_{SR,ERR}$			0.35		%
Full Scale Drift	$V_{SR,DRIFT}$			150		PPM/°C
Offset Error	$V_{SR,OS}$			10		µV
Offset Error Drift	$V_{SR,OS,DRIFT}$			0.4	2.45	µV/°C
Integral Nonlinearity Error	I_{NL}			±0.007	±0.034	FSR
Effective Input resistance	$Z_{SR,IN}$		2.5			MΩ
Input Leakage Current	$I_{SR,LKG}$				0.3	µA

ADC (TEMPERATURE AND BATTERY MEASUREMENT) CHARACTERISTICS

(V_{CC} = 3.3V. V_{BAT} = 2.45V to 5.5V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input voltage Range	$V_{ADC,IN}$		–0.2		1	V
Conversion Time	t_{SXO}	Single conversion		250		ms
Resolution		Single conversion	14		15	bits
Offset Error	$V_{ADC,OS}$			10		µV
Full Scale Error	$V_{ADC,ERR}$			0.1	0.7	%
Full Scale Drift	$V_{ADC,DRIFT}$			50		PPM/°C
Input Offset	$V_{ADC,OS}$			1		mV
Offset Error Drift	$V_{ADC,OS,DRIFT}$			2.5	18	µV/°C
Integral Nonlinearity Error	I_{NL}			±0.007	±0.034	FSR
Effective Input resistance	$Z_{ADC,IN}$		2.5			MΩ
Input Leakage Current	$I_{ADC,LKG}$				0.3	µA

DATA FLASH MEMORY CHARACTERISTICS

(V_{CC} = 3.3V. V_{BAT} = 3.3V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Data Retention	T_{DR}		10			Years

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Flash Programming Write Cycles			20000			Cycles
Row Programming Time	$t_{ROWPROG}$				2	ms
Mass Erase Time	$t_{MassErass}$				200	ms
Page Erase Time	$t_{PageErass}$				20	ms
Flash Write Supply Current	I_{CCPROG}			5	10	mA
Flash Erase Supply Current	$I_{CCERASE}$			5	10	mA

2–WIRE INTERFACE COMMUNICATION TIMING CHARACTERISTICS

(V_{CC} = 3.3V. V_{BAT} = 1.8V. C_{VCC} = 1uF. C_{REG18} = 1uF. T_A = –40°C to +85°C. Unless otherwise noted, typical values are at T_A = 25°C)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SCL Clock Frequency	f_{SCL}	(Note 1)	0		400	KHz
Bus Free Time Between a STOP and START Condition	t_{BUF}		1.3			µs
Hold Time (Repeated) START Condition	$t_{HD:STA}$	(Note 2)	0.6			µs
Low Period of SCL Clock	t_{LOW}		1.3			µs
High Period of SCL Clock	t_{HIGH}		0.6			µs
Setup Time for a Repeated START Condition	$t_{SU:STA}$		0.6			µs
Data Hold Time	$t_{HD:DAT}$	(Note 3, 4)	0		0.9	µs
Data Setup Time	$t_{SU:DAT}$	(Note 3)	100			ns
Rise Time of Both SDA and SCL Signals	t_R		20 + $0.1C_B$		300	ns
Fall Time of Both SDA and SCL Signals	t_F		20 + $0.1C_B$		300	ns
Setup Time for STOP Condition	$t_{SU:STO}$		0.6			µs
Spike Pulse Widths Suppressed by Input Filter	t_{SP}	(Note 5)	0		50	ns
Capacitive Load for Each Bus Line	C_B	(Note 6)			400	pF
SCL, SDA Input Capacitance	C_{BIN}				60	pF

Note 1: Timing must be fast enough to prevent the HY4222 from entering sleep mode due to bus low for period > t_{SLEEP}.

Note 2: f_{SCL} must meet the minimum clock low time plus the rise/fall times.

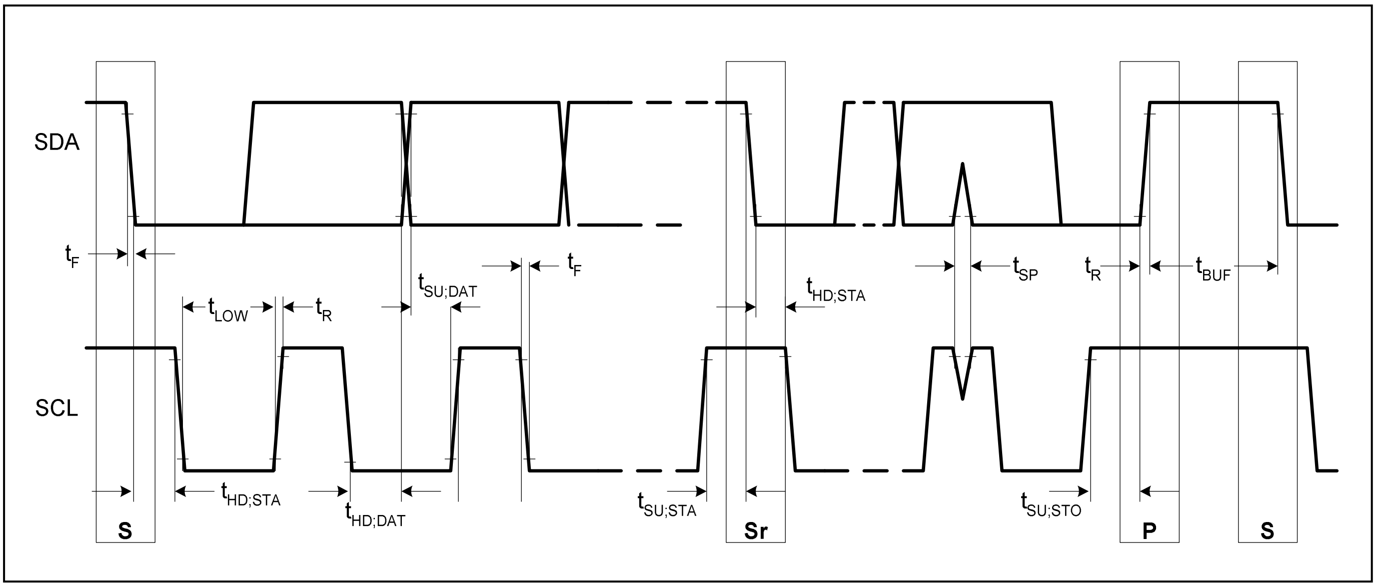
Note 3: The maximum $t_{HD:DAT}$ has only to be met if the device does not stretch the LOW period (t_{LOW}) of the SCL signal.

Note 4: This device internally provides a hold time of at least 300 ns for the SDA signal (referred to the VIHmin of the SCL signal) to bridge the undefined region of the falling edge of SCL.

Note 5: Filters on SDA and SCL suppress noise spikes at the input buffers and delay the sampling instant.

Note 6: C_b – total capacitance of one bus line in pF.

Figure 1. I²C Bus Timing Diagram



11. Data Commands

Standard Commands

The HY4222 uses a series of 2–byte standard communication protocol to enable system reading and writing of battery information. Each standard command has associated command code(s), as indicated in Table 1. Because each command consists of two bytes of data, two consecutive transmissions must be executed both to initiate the command function, and to read or write the corresponding two bytes of data. Additional options for transferring data, such as spooling, are described in Section, *I^2C Interface*. Standard commands are accessible in NORMAL mode operation. The read/write permissions depend on the NORMAL access mode, FULL ACCESS, SEALED or UNSEALED (for details about the access modes, refer to Section *Access Modes*.)

Table 1. STANDARD COMMANDS

COMMAND	SEALED[1]	UNSEALED[1]	NAME	FORMAT[2]	MINIMUM	MAXIMUM	DEFAULT	UNIT
0x00 / 0x01	R/W	R/W	Control()	Hex	0x0000	0xffff	—	—
0x02 / 0x03	R/W	R/W	AtRate()	I2	–32768	0	—	mA
0x04 / 0x05	R	R/W	AtRateTimeToEmpty()	U2	0	65535	—	minute
0x06 / 0x07	R	R/W	Temperature()	U2	0	65535	—	0.1ºK
0x08 / 0x09	R	R/W	Voltage()	U2	0	65535	—	mV
0x0a / 0x0b	R	R	Flags()	U2	0x0000	0xffff	—	—
0x0c / 0x0d	R	R/W	NominalAvailableCapacity()	U2	0	65535	—	mAh
0x0e / 0x0f	R	R/W	FullAvailableCapacity()	U2	0	65535	—	mAh
0x10 / 0x11	R	R/W	RemainingCapacity()	U2	0	65535	—	mAh
0x12 / 0x13	R	R/W	FullChargeCapacity()	U2	0	65535	—	mAh
0x14 / 0x15	R	R/W	AverageCurrent()	I2	–32768	32767	—	mA
0x16 / 0x17	R	R/W	RunTimeToEmpty()	U2	0	65535	—	minute
0x18 / 0x19	R	R/W	AverageTimeToFull()	U2	0	65535	—	minute
0x1a / 0x1b	R	R/W	StandbyCurrent()	I2	–32768	32767	—	mA
0x1c / 0x1d	R	R/W	StandbyTimeToEmpty()	U2	0	65535	—	minute
0x1e / 0x1f	R	R/W	MaxloadCurrent()	I2	–32768	32767	—	mA
0x20 / 0x21	R	R/W	MaxloadTimeToEmpty()	U2	0	65535	—	minute
0x22 to 0x27	Reserved							
0x28 / 0x29	R	R/W	InternalTemperature()	U2	0	65535	—	0.1ºK
0x2a / 0x2b	R	R/W	CycleCount()[3]	U2	0	65535	0	cycle count
0x2c / 0x2d	R	R/W	RelativeStateOfCharge()	U2	0	200	—	%

0x2e / 0x2f	R	R/W	StateOfHealth()	U2	0	200	—	% / num
0x30 / 0x31	R	R/W	Current()	I2	–32768	32767	—	mA
0x32 / 0x33	R	R	SafetyStatus()	U2	0x0000	0xffff	0x0000	—
0x34 to 0x37	Reserved							
0x70 / 0x71	R	R/W	Pack Voltage()	U2	0	65535	—	2mV

1. SEALED and UNSEALED modes are entered via commands to *Control()* plus access keys.
2. I2 = 2-byte Signed Integer; U2 = 2-byte Unsigned Integer.
3. Critical register value is automatically saved to Flash Data during NORMAL mode operation and recalled from Flash Data on Power–On–Reset procedure.

Control Commands

Issuing command *Control()* requires a series of 2–byte standard communication protocol. These additional bytes specify the specific control function desired during normal operation and features when the HY4222 is in different access modes, as indicated in Table 2.

Table 2. Control() SUBCOMMANDS

COMMAND	SEALED	FUNCTION	DESCRIPTION	DEFAULT
0x0000	R	ControlStatus()	Reports the status of data flash checksum, hibernate, etc.	0x0040
0x0001	R	DeviceType()	Reports the device type (HY4222).	0x4230
0x0002	R	FirmwareVersion()	Reports the firmware version on the device.	0x0100
0x0003	R	HardwareVersion()	Reports the hardware version on the device.	0x0001
0x0004	R	DFChecksum()	Calculates a Data Flash checksum and reports the checksum on a read.	—
0x000c	R	DFVersion()	Reports the Data Flash version on the device.	—
0x0010	W	SetFullSleep()	Forces ControlStatus().FULLSLEEP to 1.	—
0x0011	W	SetHibernate()	Forces ControlStatus().HIBERNATE to 1.	—
0x0012	W	ClearHibernate()	Forces ControlStatus().HIBERNATE to 0.	—
0x0013	No	SetShutdown()	Enables the SE pin to change state.	—
0x0014	No	ClearShutdown()	Disables the SE pin from changing state.	—
0x0020	No	SealedDevice()	Places the device into SEALED state.	—
0x0022	R	IFChecksum()	Calculates an Instruction Flash checksum and reports the checksum on a read.	—
0x0040	No	CalibrationMode()	Places the device in calibration mode.	—
0x0041	No	Reset()	Forces a full reset of the device. It is a one-shot action.	—
0x0042	W	QuickStart()	Forces a re-calculation about capacity information.	—
0x0046	W	ClearLearned()	Forces Flag().LRND to 0.	—
0x0051	W	LEDsON()	Force enabled LEDs turned on for a LED hold time.	—
0x0052	W	LEDsOFF()	Force enabled LEDs turned off for a LED hold time.	—
0x0053	W	DisplayON()	Force activated LEDs to simulate the function of /DISP pin.	—

Extended Commands

Extended commands offer more functionality beyond the standard commands. Each extended command has associated command code(s), as indicated in Table 3. The command code(s) is not limited to be a 2–byte word. The read/write permissions depend on the NORMAL access mode, FULL ACCESS, SEALED or UNSEALED (for details about the access modes, refer to Section *Access Modes*.)

Table 3. EXTENDED COMMANDS

COMMAND	SEALED	UNSEALED	DESCRIPTION	FORMAT[1]	UNIT
0x38	R	R	WakeCurrentThreshold()	I1	mV
0x39	R	R	Operation Cfg B()	Hex	—
0x3a / 0x3b	R	R	Operation Cfg A()	Hex	—
0x3c / 0x3d	R	R	DesignCapacity()	U2	mAh
0x3e	N/A	R/W	DataFlashClass()[2]	Hex	—
0x3f	N/A	R/W	DataFlashBlock()[2]	Hex	—
0x40 to 0x53	R/W	R/W	BlockData() / Authenticate()[3]	Hex	—
0x54	R/W	R/W	BlockData() / AuthenticateCheckSum()[3]	Hex	—
0x55 to 0x5f	R	R/W	BlockData()	Hex	—
0x60	R/W	R/W	BlockDataChecksum()	Hex	—
0x61	R/W	R/W	BlockDataControl()	Hex	—
0x62	R	R	DeviceNameLength()	Hex	—
0x63 to 0x69	R	R	DeviceName()	Hex	—

1. I1 = 1-byte Signed Integer; U2 = 2-byte Unsigned Integer.
2. In SEALED mode, Data Flash CANNOT be accessed through commands 0x3e and 0x3f.
3. The BlockData( ) command area shares functionality for accessing general data flash and for using Authentication.

Data Flash

In HY4222, Data Flash is a non–volatile memory that contains initialization default values, battery status, calibration information, configuration information, and application information. The Data Flash can be access in several different ways, depending on what mode the HY4222 is operating in and what data is being accessed. The Data Flash locations are summarized in Table 5.

Table 5. DATA Flash SUMMARY

CLASS	SUBCLASS ID	SUBCLASS	OFFSET	FORMATE	NAME	MINIMUM	MAXIMUM	DEFAULT	UNIT
1st Level Safety	1	Voltage	0	I2	Low Temp Over Voltage (LT OV) Threshold	3400	5000	4300	mV
1st Level Safety	1	Voltage	2	I2	Low Temp Over Voltage (LT OV) Recovery	0	4400	3900	mV
1st Level Safety	1	Voltage	4	I2	Standard Temp Over Voltage (ST OV) Threshold	3400	5000	4500	mV
1st Level Safety	1	Voltage	6	I2	Standard Temp Over Voltage (ST OV) Recovery	0	4400	4100	mV
1st Level Safety	1	Voltage	8	I2	High Temp Over Voltage (HT OV) Threshold	3400	5000	4400	mV
1st Level Safety	1	Voltage	10	I2	High Temp Over Voltage (HT OV) Recovery	0	4400	4000	mV
1st Level Safety	1	Voltage	12	U1	Over Voltage (OV) Time	0	240	8	s
1st Level Safety	1	Voltage	13	I2	Under Voltage (UV) Threshold	0	3500	2200	mV
1st Level Safety	1	Voltage	15	I2	Under Voltage (UV) Recovery	0	3600	3000	mV
1st Level Safety	1	Voltage	17	U1	Under Voltage (UV) Time	0	240	8	s
1st Level Safety	1	Current	32	I2	Charge Over Current (COC) Threshold	0	65535	6000	mA
1st Level Safety	1	Current	34	I2	Charge Over Current (COC) Recovery	0	65535	300	mA
1st Level Safety	1	Current	36	U1	Charge Over Current (COC) Time	0	240	8	s

1st Level Safety	1	Current	38	I2	Discharge Over Current (DOC) Threshold	0	65535	6000	mA
1st Level Safety	1	Current	40	I2	Discharge Over Current (DOC) Recovery	0	65535	300	mA
1st Level Safety	1	Current	42	U1	Discharge Over Current (DOC) Time	0	240	8	s
1st Level Safety	1	Current	50	U1	Current Recovery Time	0	240	8	s
1st Level Safety	1	Temp	71	I2	Charge Over Temp 1 (COT1) Threshold	0	2550	550	0.1ºC
1st Level Safety	1	Temp	66	U1	Charge Over Temp 1 (COT1) Time	0	240	2	s
1st Level Safety	1	Temp	67	I2	Charge Over Temp 1 (COT1) Recovery	0	2550	500	0.1ºC
1st Level Safety	1	Temp	74	I2	Discharge Over Temp 1 (DOT1) Threshold	0	2550	600	0.1ºC
1st Level Safety	1	Temp	76	U1	Discharge Over Temp 1 (DOT1) Time	0	240	2	s
1st Level Safety	1	Temp	77	I2	Discharge Over Temp 1 (DOT1) Recovery	0	2550	550	0.1ºC
1st Level Safety	1	Temp	84	I2	Discharge Start High Temp (DHT) Threshold	0	1200	600	0.1ºC
1st Level Safety	1	Temp	86	I2	Discharge Start High Temp (DHT) Recovery	0	1200	550	0.1ºC
Charge Ctrl	5	Charge Temp	0	I2	JEITA Temp 1 (JT1)	–400	1200	0	0.1ºC
Charge Ctrl	5	Charge Temp	2	I2	JEITA Temp 2 (JT2)	–400	1200	120	0.1ºC
Charge Ctrl	5	Charge Temp	4	I2	JEITA Temp 3 (JT3)	–400	1200	450	0.1ºC
Charge Ctrl	5	Charge Temp	6	I2	JEITA Temp 4 (JT4)	–400	1200	550	0.1ºC
Charge Ctrl	5	Charge Temp	8	I2	Temp Hysteresis	0	100	10	0.1ºC
General Cfg	3	General Data	0	H1	Operation Cfg B	0x00	0xff	0xF0	—
General Cfg	3	General Data	1	H1	Operation Cfg A High	0x00	0xff	0xB3	—
General Cfg	3	General Data	2	H1	Operation Cfg A Low	0x00	0xff	0x00	—

Battery Cfg	3	Battery Data	3	I2	Design Capacity (DC)	0	32767	1000	mAh
Battery Cfg	3	Battery Data	5	U2	Design Age	0	25600	640	(1/256)% per 100 cycles
Battery Cfg	3	Battery Data	7	I2	Termination Voltage	0	4500	3000	mV
Charge Ctrl	3	Charge Termination	11	I2	Charging Voltage	0	1000	4100	mV
Charge Ctrl	3	Charge Termination	13	I1	Taper Voltage	0	1000	100	mV
Charge Ctrl	3	Charge Termination	14	I2	Taper Current	0	1000	100	mA
Charge Ctrl	3	Charge Termination	16	I1	Current Taper Window	0	60	40	s
Charge Ctrl	3	Charge Termination	17	I1	Minimum Taper Charge	0	1000	25	0.01mAh
Gauge	3	Current Data	18	I2	Initial Maximum Current	–32767	0	–200	mA
Gauge	3	Current Data	20	I2	Initial Standby Current	–256	0	–10	mA
Gauge	3	Current Data	22	I2	State Of Health Current	–32767	0	–400	mA
Gauge	3	Current Threshold	24	I2	Quit Current Threshold	0	1000	10	mA
Gauge	3	Learning Threshold	28	H1	Relaxation Voltage Time Threshold	0x00	0xff	0x10	—
Gauge	3	Learning Threshold	29	U1	SOC Delta Threshold	0	255	30	%
Gauge	3	Learning Threshold	30	U1	SOC Learning Qualification Threshold	0	255	15	%
Gauge	3	Learning Threshold	31	U1	SOC Learning High Threshold	0	255	40	%
Gauge	3	Learning Threshold	32	U1	SOC Learning Low Threshold	0	255	20	%
Gauge	3	Capacity Threshold	33	I2	SOC1 Set Threshold	0	255	82	4mAh
Gauge	3	Capacity Threshold	35	I2	SOC1 Clear Threshold	0	255	96	4mAh
Gauge	3	Capacity Threshold	37	I2	SOCF Set Threshold	0	255	41	4mAh
Gauge	3	Capacity Threshold	39	I2	SOCF Clear Threshold	0	255	55	4mAh
Gauge	3	Current Sense	41	I2	Sense Resistor	0	65535	10000	µΩ

Gauge	3	Current Sense	43	I2	Sense Resistor Temp Coefficient	–3840	3840	0	0.117 ppm/ºK
Power	3	Current Threshold	45	I1	Sleep Current	0	100	8	mA
Power	3	Current Threshold	46	I1	Hibernate Current	0	255	3	mA
Power	3	Voltage Threshold	47	I2	Hibernate Voltage	2400	3000	2550	mV
Power	3	Current Threshold	49	I2	Charge Current Threshold	0	1000	40	mA
Power	3	Current Threshold	51	I1	Discharge Current Threshold	0	255	30	mA
Power	3	Time Threshold	52	U1	Full Sleep Wait Time	0	255	0	s
Power	3	Current Threshold	53	I1	Wake Current Threshold	0	255	10	mV
Flash Cfg	3	Voltage Threshold	56	I2	Flash Update OK Voltage	2000	20000	3100	mV
Gauge	3	Capacity Data	58	I2	Reserve Capacity	0	9000	0	mAh
Gauge	3	Capacity Data	60	I2	Empty Detect Slope	0	2000	3	mV/%
Gauge	3	Capacity Data	61	I1	Empty Detect Count	0	100	3	count
LED Support	3	LED Cfg	96	I1	LED Flash Period	0	255	1	0.1m
LED Support	3	LED Cfg	97	I1	LED Blink Period	0	255	2	0.1m
LED Support	3	LED Cfg	98	I1	LED Hold Time	0	255	40	0.1m
LED Support	3	LED Cfg	99	I1	LED Delay Time	0	255	10	0.1m
Manufacture Data	6	Manufacture Data	0	H2	Pack Lot Code	0x0000	0xffff	0x0000	—
Manufacture Data	6	Manufacture Data	2	H2	PCB Lot Code	0x0000	0xffff	0x0000	—
Manufacture Data	6	Manufacture Data	4	H2	Firmware Revision	0x0000	0xffff	0x0110	—
Manufacture Data	6	Manufacture Data	6	H2	Hardware Revision	0x0000	0xffff	0x0010	—
Manufacture	6	Manufacture	8	H2	Cell Revision	0x0000	0xffff	0x0000	—

Data		Data							
Manufacture Data	6	Manufacture Data	10	H2	Flash Data Revision	0x0000	0xffff	0x0000	—
Manufacture Data	6	Manufacture Data	12	H2	Device Type	0x0000	0xffff	0x4230	—
Manufacture Data	6	Manufacture Data	32	H2	Specification Info	0x0000	0xffff	0x0031	—
Manufacture Data	6	Manufacture Data	34	U2	Manufacturer Date	0	65535	0	—
Manufacture Data	6	Manufacture Data	36	H2	Serial Number	0x0000	0xffff	0x0001	—
Manufacture Data	6	Manufacture Data	38	S21	Manufacturer Name	—	—	Hycontek	ASCII
Manufacture Data	6	Manufacture Data	50	S21	Device Name	—	—	HY4222	ASCII
Manufacture Data	6	Manufacture Data	58	S5	Device Chemistry	—	—	LIFP	ASCII
Manufacturer Info	32	Manufacturer Info	0 – 31	S32	Block A [0 – 31]	—	—	0123456789ABCDEF0123456789ABCDE	—
Manufacturer Info	32	Manufacturer Info	32 – 63	S32	Block B [0 – 31]	—	—	0123456789ABCDEF012	—
Manufacturer Info	32	Manufacturer Info	64 – 95	S32	Block C [0 – 31]	—	—	0123456789ABCDEF012	—
Thermistor	30	Data	0 – 93	I47	Thermistor Info	—	—	—	—
Lifetime Data	9	Temp Data	0	I2	Lifetime Maximum Temp	0	1400	300	0.1ºC
Lifetime Data	9	Temp Data	2	I2	Lifetime Minimum Temp	0	1400	200	0.1ºC
Lifetime Data	9	Voltage Data	4	I2	Lifetime Maximum Cell Voltage	0	32767	3500	mV
Lifetime Data	9	Voltage Data	6	I2	Lifetime Minimum Cell Voltage	0	32767	3200	mV
Lifetime Data	9	Current Data	12	I2	Lifetime Maximum Charge Current	–32767	32767	1500	mA
Lifetime Data	9	Current Data	14	I2	Lifetime Maximum Discharge Current	–32767	32767	–3000	mA

Gauge	9	Battery Data	76	I2	Design Capacity	0	32767	1000	mAh
Gauge	9	Battery Data	78	U2	Cycle Count	0	65535	0	Cycle
Gauge	9	Battery Data	80	I2	Cell Age	0	3200	1000	0.1%
Lifetime Data	9	Current Data	82	I2	Lifetime Maximum Average Discharge Current	–32767	32767	–1000	mA
Lifetime Data	9	Temp Data	84	I2	Lifetime Average Temp	0	1400	250	0.1ºC
Lifetime Data	9	Temp Data	86	I2	Lifetime Over Temp Count	0	65535	0	count
Lifetime Data	9	Temp Data	88	I2	Lifetime Over Temp Duration	0	65535	0	s
Lifetime Data	9	Voltage Data	90	I2	Lifetime Over Voltage Count	0	65535	0	count
Lifetime Data	9	Voltage Data	92	I2	Lifetime Over Voltage Duration	0	65535	0	s
Lifetime Data	9	Temp Data	94	I4	Lifetime Temp Sample Count	0	140000000	0	num
Lifetime Data	9	Flash Data	96	I2	Lifetime Flash Update Count	0	32767	0	num
Lifetime Data	7	Resolution	0	I1	Lifetime Temp Resolution	0	255	10	0.1ºC
Lifetime Data	7	Resolution	1	I1	Lifetime Voltage Resolution	0	255	25	mV
Lifetime Data	7	Resolution	2	I1	Lifetime Current Resolution	0	255	100	mA
Lifetime Data	7	Resolution	3	I1	Lifetime Update Time	0	65535	60	s
Calibration	2	Data	0	I3	CC Gain	—	—	—	—
Calibration	2	Data	3	I3	Voltage Gain	—	—	—	—
Calibration	2	Data	8	I2	Internal Temp Gain	—	—	—	—
Calibration	2	Data	6	I2	External Temp 1 Gain	—	—	—	—
Calibration	2	Data	10	I3	CC Offset	—	—	—	—
Calibration	2	Data	17	I4	CC Count	—	—	—	—
Calibration	2	Data	19	U1	CC Time	0	255	180	s
Security	31	Codes	0	H4	Unseal Key 0	0x00000000	0xffffffff	0x28804288	—
Security	31	Codes	8	H4	Unseal Key 1	0x00000000	0xffffffff	0x28751690	—
Security	31	Codes	4	H4	Full Access Key 0	0x00000000	0xffffffff	0xffffffff	—
Security	31	Codes	12	H4	Full Access Key 1	0x00000000	0xffffffff	0xffffffff	—

Note: (1) Encoded battery profile information created by HY4222EV software.

12. Detailed Description

Manufacturer Information Blocks

The HY4222 contains 96 bytes of user programmable Data Flash storage: Manufacturer Info Block A, Manufacturer Info Block B, Manufacturer Info Block C. The method for accessing these memory locations is slightly different, depending on whether the device is in FULL ACCESS, UNSEALED, or SEALED mode.

Access Modes

The HY4222 provides three security modes (FULL ACCESS, UNSEALED, and SEALED) that control Data Flash access permissions according to Table 4. Data Flash locations, specified in Table 5, are accessible to user. Manufacturer information refers to the three reserved 32–byte blocks.

Table 4. Data Flash Access

SECURITY MODE	DATA FLASH ACCESS	MANUFACTURER INFORMATION	KEY ACCESS
FULL ACCESS	R/W	R/W	R/W
UNSEALED ACCESS	R/W	R/W	R
SEALED ACCESS	NONE	R (A); R/W (B, C)	NONE

Only the FULL ACCESS mode allows the HY4222 to write the access–mode transition keys: Full Access Key and Unseal Key.

Battery Parameter Measurement

The HY4222 uses two sets of ADCs to make voltage, temperature and current measurements. Measurement sequence repeats continuously while the HY4222 is in NORMAL mode. All measured results can be accessed via I^2C interface.

Voltage Measurement

The battery voltage is measured across the positive and negative terminals of battery pack periodically. The values are updated within 1 second.

Temperature Measurement

The HY4222 uses the integrated temperature sensor and an external thermistor network to measure temperature. The values are updated within 1 second. Characteristics of the external thermistor can be programmed into Data Flash. Depending on the setting of *[TEMPS]* bit in *Operation Cfg A()* register, the device will use the selected temperature measurement for capacity estimate.

Current Measurement

The HY4222 continually measures the current flow into and out of battery by measuring the voltage drop across a low value, approximately 10mΩ, current sense resistor, R_{SNS}. The voltage sense range between the SRP and SRN pins is ±160mV with a resolution of 1mA. The HY4222 detects charge activity when $V_{SR} = V_{SRP} - V_{SRN}$ is positive, and discharge activity when $V_{SR} = V_{SRP} - V_{SRN}$ is negative. The values are updated within 1 second.

Charge and Discharge Coulomb Counting

The HY4222 continuously integrates the current measurements over time, using an internal counter. The fundamental rate of the counter is 0.65nVh.

Power Modes

The HY4222 has four power modes: NORMAL, SLEEP, FULLSLEEP, and HIBERNATE. In NORMAL mode, the HY4222 is fully powered and executes any allowable task. Otherwise, the HY4222 operates in other power saving modes, if the battery voltage is above the Power–On–Reset (POR) threshold voltage.

Shutdown Enable (SE Pin)

The SE pin indicates the HIBERNATE mode. The feature is useful to shutdown any device in a deeply discharged battery to protect the battery. Note that the SE pin can not indicate the HIBERNATE mode and used as the shutdown feature during Power–On–Reset (POR).

The following bits are use to configure and control SE pin:

- One *Operation Cfg A()* bit, also stored in Data Flash, enables or disables the System Shutdown functionality.
  - SE_EN bit: If set, enable the System Shutdown functionality, and the SE pin is active. Default is 1.
- Two *Control*() subcommands enable or disable the System Shutdown functionality.

  - *SetShutdown()* (0x0013): Enable the System Shutdown functionality, activate the SE pin, and set the SHUTDOWN bit *ControlStatus()*.
  - *ClearShutdown()* (0x0014): Disable the System Shutdown functionality, pull the SE pin down, and clear the SHUTDOWN bit in *ControlStatus()*.
- Two *ControlStatus()* bits indicate the status on SE pin.
  - SE (default = 0): If set, the SE pin is active by SE_EN bit in *Operation Cfg A()*.
  - SHUTDOWN (default = 0): If set, the System Shutdown functionality is enabled by the *SetShutdown()* subcommand.
- Two *Operation Cfg A()* bits, also stored in Data Flash, bits control the state of the SE pin.
  - SE_POL (default = 1): If set, active high to indicate the System Shutdown state on the SE pin.

Temperature Good (/TGD Pin)

The pull-down /TGD pin indicates the battery operation temperature is under safe range. The pin is pulled high if a temperature safety protection is detected. The feature is useful to turn off current path to battery if a temperature safety protection is detected. Note that the /TGD pin can not indicate the safety alerts during Power–On–Reset (POR).

Charge Termination Enable (STPCHG Pin)

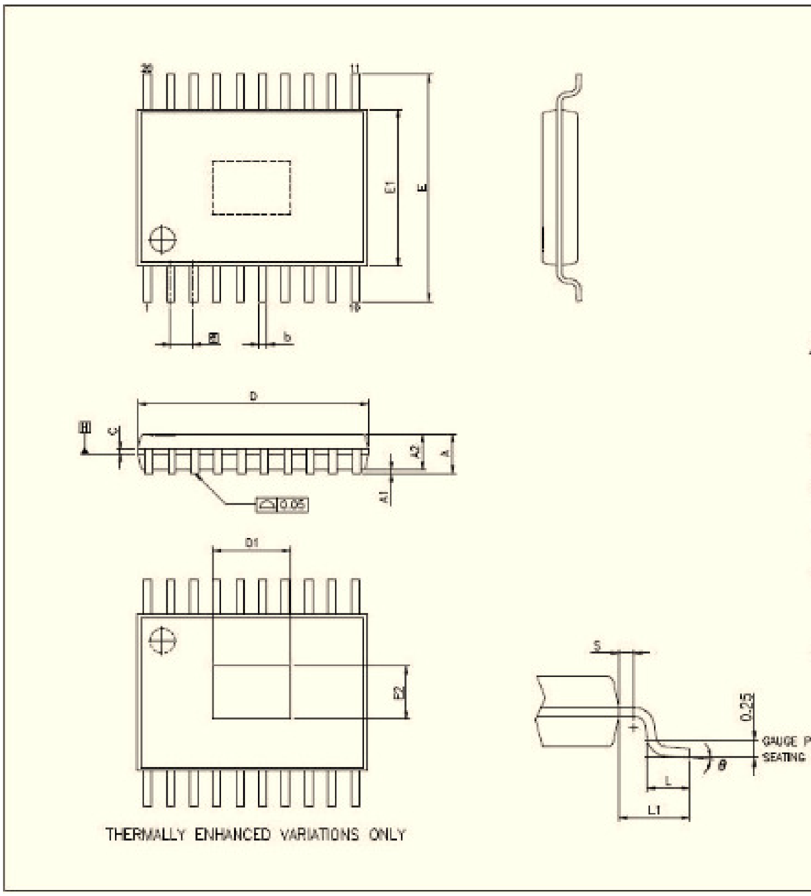
The asserted STPCHG pin functions as the input to indicate the device a Charge Termination state happening. Either the Charge Termination threshold set in Flash memory satisfied or the STPCHG pin asserted can indicate a fully charged battery.

The following bits are use to configure and control STPCHG pin:

- One *Operation Cfg B()* bit, also stored in Data Flash, enables or disables the System Shutdown functionality.
  - STP_EN bit: If set, enable the Charge Termination functionality, and the STPCHG pin is active. Default is 1.
- One *Operation Cfg B()* bits, also stored in Data Flash, bits control the state of the STPCHG pin.
  - STP_POL (default = 1): If set, active high to indicate the device the Charge Termination state happening through the STPCHG pin.

13. Operation Example

14. Package Information



VARIATIONS (ALL DIMENSIONS SHOWN IN MM)

SYMBOLS	MIN.	NOM.	MAX.
A	–	–	1.20
A1	0.05	–	0.15
A2	0.80	0.90	1.05
b	0.19	–	0.30
C	0.09	–	0.20
D	6.40	6.50	6.60
E1	4.30	4.40	4.50
E	6.40 BSC		
e	0.65 BSC		
L1	1.00 REF		
L	0.50	0.60	0.75
S	0.20	–	–
θ	0°	–	8°

THERMALLY ENHANCED DIMENSIONS(SHOWN IN MM)

PAD SIZE	E2			D1		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
118X16E	2.60	2.80	3.00	3.79	3.99	4.19

NOTES:
1. JEDEC OUTLINE : MO-153 AC/MO-153 ACT(THERMALLY ENHANCED VARIATIONS ONLY)
2. DIMENSION 'D' DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.15 PER SIDE.
3. DIMENSION 'E1' DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 PER SIDE.
4. DIMENSION 'b' DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 MM TOTAL IN EXCESS OF THE 'b' DIMENSION AT MAXIMUM MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OF THE FOOT. MINIMUM SPACE BETWEEN PROTRUSION AND ADJACENT LEAD IS 0.07 MM.
5. DIMENSIONS 'D' AND 'E1' TO BE DETERMINED AT DATUM PLANE H .

15. Revision Record

Major differences are stated thereinafter:

Version	Page	Revision Summary
1.0	29	New
1.1	29	Updated from 1.0
1.2	31	Updated from 1.1
1.3	31	Updated from 1.2
1.4	31	Updated from 1.3
1.5	31	Updated from 1.4
1.6	30	Updated from 1.5