

HESC-UPS Manual

High Efficiency & Smart Charging Uninterruptible Power Supply Firmware Manual

For HESC products featuring
Microchip PIC16F microprocessors

Designed by

TRI-M ENGINEERING

Engineered Solutions for Embedded Applications

Technical Manual

P/N: HESC-UPS

For firmware Rev 2.24 or higher.

Includes new settings for 2U27

Revision: 27-June-05

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PREFACE

This manual is for integrators of applications of embedded systems. It contains information on hardware and software requirements and interconnection to other embedded electronics.

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Table of Contents

Section 1 : HESC Overview	6
Section 2 : Start-up and Shut-down settings, delays, and functions.....	6
Section 3 : HESC-SER SerBus Communications.....	8
A. Description:	8
B. Slave Mode:	8
Section 4 : HESC104 PC/104 Bus Communications	9
A. Description:	9
B. Slave Mode:	9
Section 5 : HESC I ² C/SMBus Bus Communications	10
A. Description:	10
Section 6 : SerBus, SMBus, and PC/104 Command Functions	10
A. List of Command Functions	10
B. HESC Function Command Details.....	12
1. BattTempCmd() 0x08.....	12
2. BattVCmd() 0x09.....	12
3. BattICmd() 0x0A.....	12
4. BattIavgCmd() 0x0B.....	12
5. BattRemCapCmd() 0x0F	13
6. ChargerSpecInfoCmd() 0x11	13
7. ChargerModeCmd() 0x12	13
8. ChargerStatusCmd() 0x13	14
9. ChargingCurrentCmd() 0x14.....	16
10. ChargingVoltageCmd() 0x15	16
11. AlarmWarningCmd() 0x16	17
12. GetVersionCmd() (0x3E)	18
13. SerialNumber() (0x3F)	18
14. GetI2CTempCmd0() (0x80) to GetI2CTempCmd15() (0x8F).....	18
15. TempThCmd() (0x90).....	18
16. MainVCmd() (0x91).....	19
17. MainICmd() (0x92)	19
18. InputPwrCmd() (0x93).....	19
19. BattPwrCmd() (0x94)	19
20. ChCycleCmd() (0x95)	20
21. ChTermLastCmd() (0x96)	20
22. ShutDownCmd() (0x97)	20
23. PowerSupplyStatusCmd() (0x98)	21
24. SDSUCauseCmd() (0x99)	21
25. ActiveEEcmd() (0xA0).....	22
26. EEPromCmd () (0xA1).....	22
Section 7 : EEprom Setpoints and Configuration Variables	23
A. List of EEprom Setpoints and Configuration Variable.....	23
B. SerBus EEprom Details	25
1. ChTerm - EEprom Locations 0x00, 0x20, 0x40, 0x60:	25
2. Spare - EEprom Locations 0x02 0x22 0x42 0x62	25
3. Spare - EEprom Locations 0x04 0x24 0x44 0x64	25
4. BattVmaxDef - EEprom Locations 0x06, 0x26, 0x46, 0x66:.....	25
5. BattVmaxTimeDef - EEprom Locations 0x08, 0x28, 0x48, 0x68:.....	26
6. BattVdeltaDef - EEprom Locations 0x0A, 0x2A, 0x4A, 0x6A:	26
7. TimeMaxDef - EEprom Locations 0x0C, 0x2C, 0x4C, 0x6C:.....	26
8. BattIminDef - EEprom Locations 0x0E, 0x2E, 0x4E, 0x6E:.....	26
9. BattIminDef - EEprom Locations 0x10, 0x30, 0x50, 0x70:	27
10. TimeTermEnDef - EEprom Locations 0x12, 0x32, 0x52, 0x72:	27
11. BattTempCompDef - EEprom Locations 0x14, 0x34, 0x54, 0x74:.....	27

12.	BattVDef - EEprom Locations 0x16, 0x36, 0x56, 0x76:.....	27
13.	BattIDef - EEprom Locations 0x18, 0x38, 0x58, 0x78:	28
14.	BattTempRateDef - EEprom Locations 0x1A, 0x3A, 0x5A, 0x7A:	28
15.	BattTrickleDef - EEprom Locations 0x1C, 0x3C, 0x5C, 0x7C:	28
16.	BattTrickleTimeDef - EEprom Locations 0x1E, 0x3E, 0x5E, 0x7E:.....	28
17.	ChFlagsDef - EEprom Locations 0x80;.....	29
18.	BattLowVoltageDef – EEprom Locations 0x82	29
19.	BattLowCapacityDef – EEprom Locations 0x84	29
20.	MainPwrMaxDef – EEprom Locations 0x86, 0x87	29
21.	MaxBusTimeDef – EEprom Locations 0x88	30
22.	CHCycleMaxDef – EEprom Locations 0x89	30
23.	BattTempMinDef - EEprom Locations 0x8A:	30
24.	BattTempMaxDef - EEprom Locations 8C:.....	30
25.	BattVminDef - EEprom Locations 0x8E:	30
26.	ChTempSelectDef (0x90)	31
27.	I2CpollTimeDef - EEprom Locations 0x92, 0x93	31
28.	I2CTsiCenDef - EEprom Locations 0x94.....	31
29.	PWRSDebDef (0xD0), PWRSUdebDef (0xD2), IGNSDdebDef (0xD8), IGNSUdebDef (0xDA)	32
30.	PWRSDDef (0xD4), IGNSDDef (0xDC), PBSDDef (0xE0), BATTSDDef (0xE4), Cmd98SDDef (0xE6)	32
31.	PWRSUDef (0xD6), IGNSUDef (0xDE), PBSUDef (0xE2), Cmd98SUDef (0xE8).....	32
32.	SDStartupDelayDef (0xF8), (New in version 2U28)	32
33.	BattMaxCapDef – EEprom Locations 0xFA, 0xFB (New in version 2U27)	33
34.	BattRemCapDef – EEprom Locations 0xFC, 0xFD (New in version 2U27)	33
35.	BattTime2RechargeDef - EEprom Locations 0xFE, 0xFF:.....	33
	Section 8 : Temperature Sensor, TS-IC and Controller, TC-IC	34
	Section 9 : Battery Charging Algorithms and Strategies.....	35
	A. Sealed Lead Acid, SLA	35
	1. Single Stage Charging	35
	2. Dual Stage Charging.....	35
	Section 10 HESC-UPS FIRMWARE UPDATE PROCEDURE	37
	Section 11 : Implementing a smart “Watchdog Timer” on the Host CPU	38
	Section 12 : LED Operation	39
	Section 13 : UPS function for Windows compatibility	40

Table 1, List of HESC Command Functions	10
Table 2, ChargerSpecInfoCmd bit map.....	13
Table 3, ChargerModeCmd bit map.....	14
Table 4, ChargerStatusCmd bit map.....	15
Table 5, AlarmWarningCmd bit map.....	17
Table 6, ChTermLastCmd bit map.....	20
Table 7, PowerSupplyStatusCmd bit map	21
Table 8, SDSUCauseCmd bit map	22
Table 9, HESC Setpoints and Configuration Variables.....	23
Table 10, ChTerm bit map	25
Table 11, ChFlags bit map.....	29
Table 12, Temperature device selection values:	31
Table 13, TS-IC and TC-IC device enable settings:.....	32
Table 14, Temperature Sensor and Temperature Controller bit map	34
Table 15, SLA Single Stage Charging Set-up	35
Table 16, SLA Two Stage Charging Set-up.....	36
Table 17, Heatbeat LED toggle rates	39
Table 18, Charger LED operation.....	39

Section 1 : HESC Overview

The High Efficiency & Smart Charging (HESC) product line includes the HESC-SER and HESC104. Command, control, monitoring and datalogging via the SMBus are the same for both the HESC-SER and HESC104. However, the HESC-SER also has an RS232 serial port and the HESC104 has a PC/104 bus interface. The serial port and PC/104 bus interface are in most instances connected only to the Host CPU, however other devices may also make use of these ports. For example, it is possible that a battery pack could be built with an RS232 serial port and it could be connected to the HESC-SER serial port.

Throughout this manual, use of the term HESC refers to any of the HESC products, while use of the name HESC-SER or HESC104 refers strictly to a particular product. From the command function point of view, there are few differences between the HESC-SER and the HESC104 even though they have different Host interfaces (the SMBus is usually thought of as a battery interface, but it may also interface with a Host CPU or a microcontroller). Whenever there are any differences in the commands functions for the different HESC models, they will be noted in the command function description.

The HESC can be set-up to provide up to four stages of charging for standard battery packs. Changing from one cycle to the next is accomplished by setting the charge termination flags and values. When one of the charge termination methods is satisfied, the next charging stage values are retrieved from the EEprom. If the current cycle is the last cycle enabled, then charging will be terminated. Additionally, the Host can directly command the HESC to change charging cycles.

Section 2 : Start-up and Shut-down settings, delays, and functions

The HESC-UPS firmware power management system works well with advanced operating systems such as Windows, and Linux. It is imperative with the advanced operating systems that an orderly shutdown of the files be down of the application program and operating system. Failure to allow for orderly shutdown can cause data loss, intermittent crashes, or a complete unrecoverable system failure.

The HESC-UPS firmware has three internal modes that control the start up and shut down of the HESC outputs.

1. Debounce

HESC-UPS firmware "debounces" the main power and the IGN input start up and shut down requests by requiring the cause of the request to remain valid for the debounce interval. There is separate shut down and start up debounce definitions for both main power and the IGN input. The debounce time can be set from zero to 65535 seconds. The HESC-UPS provide this debouncing to prevent nuisance shut downs or start-ups.

2. Start-Up

The HESC-UPS firmware sets the Start-Up request flag, and begins the Start-Up mode after receiving a start up request. (The Start-Up request flag can be read with PowerSupplyStatusCmd.) The Start-Up mode is initiated by loading the Start-Up timer with the Start-Up interval assigned to the Start-Up request cause. If the HESC is already in Start-Up mode when a new Start-Up request is received, the Start-Up timer will be loaded with the new Start-Up interval if it is less than the existing Start-Up timer count. When the Start-Up timer expires, the HESC outputs are turned on. During Start-Up mode, the CPU LED will blink rapidly (2 Hz). If a Shut-Down request is received while a Start-Up request is active, the current active Start-Up request will be cancelled.

Start-Up requests are generated by:

- When the HESC has main power applied.
- When the IGN input of the HESC-SER is taken to the "On" state. The polarity of the IGN is programmable, so the state of the input (high or low) will depend on the polarity setting.
- When the SD input of the HESC104 is taken to the "On" state. The polarity of the SD is programmable, so the state of the input (high or low) will depend on the polarity setting.
- When the Pushbutton Shutdown (SD) input is energized, and the HESC-SER is off or is in the shutdown mode.
- When the Pushbutton Shutdown (PS) input is pulled to Common, and the HESC104 is off or is in the shutdown mode.

- When the Host CPU writes command PowerSupplyStatusCmd with bit 7 set, either through the SerBus, PC/104 bus or the I2C/SMBus.

Note: Setting a shut down interval to zero prevents Shut-Down request being issued from it's cause.

3. Shut-Down

The HESC-UPS firmware sets the Shut-Down request flag, and begins the Shut-Down mode after receiving a shut down request. (The Shut-Down request flag can be read with PowerSupplyStatusCmd.) The Shut-Down mode begins by loading the Shut-Down timer with the Shut-Down interval assigned to the Shut-Down request cause. If the HESC is already in Shut-Down mode when a new Shut-Down request is received, the Shut-Down timer will be loaded with the new Shut-Down interval if it is less than the existing Shut-Down timer count. When the Shut-Down timer expires, the HESC outputs are turned off. During Shut-Down mode, the CPU LED will blink slowly (0.5 Hz).). If a Start-Up request is received while a Shut-Down request is active, the Start-Up request will be "registered" and take effect after the Shut-Down mode is complete. The only method to cancel a Shut-Down mode in progress is by a Host CPU using command PowerSupplyStatusCmd with bit 8 cleared.

Shut-Down requests are generated by:

- When the HESC main power is removed.
- When the IGN input of the HESC-SER is taken to the "Off" state. The polarity of the IGN is programmable, so the state of the input (high or low) will depend on the polarity setting.
- When the SD input of the HESC104 is taken to the "Off" state. The polarity of the IGN is programmable, so the state of the input (high or low) will depend on the polarity setting.
- When the Pushbutton Shutdown (SD) input is energized, and the HESC-SER is on.
- When the Pushbutton Shutdown (PS) input is pulled to Common, and the HESC104 is on.
- When the Host CPU writes command PowerSupplyStatusCmd with bit 8 set, either through the SerBus, PC/104 bus or the I2C/SMBus.
- When the Host CPU writes command ShutDownCmd to the HESC through the SerBus, PC/104 bus or the I2C/SMBus.
- When the battery voltage or battery capacity falls below the BattLowVoltageDef or BattLowCapacityDef levels.

Note: Setting a shut down interval to zero prevents a Shut-Down request being issued.

Feature: Writing command PowerSupplyStatusCmd with bits 7 & 8 set will result in the HESC turning off the outputs after the Shut-Down interval, and turning on the outputs after the Start-Up interval. This is useful for remote data logging systems that only need to be on for brief intervals, then turned back off to conserve power.

Section 3 : HESC-SER SerBus Communications

A. Description:

The HESC-SER communicates with the Host through the asynchronous serial bus. Commands and data are sent and received using a full duplex 8 bit, no parity, 9600 baud, and one stop bit format. The HESC-SER operates in a "slave" mode where the Host initiates all the communications between the HESC-SER and the Host.

- Table 1 lists the commands the HESC supports.

To ensure reliable communication, an acknowledge byte is returned after each address, command or data byte transmitted. The receiving device (HESC-SER or Host) must acknowledge receipt of each byte, unless the bus timer is turned off. If an acknowledge byte doesn't match the acknowledge number expected then a "collision" is deemed to have occurred. The transaction is aborted immediately and the result byte set accordingly.

An "enhanced" communication mode is available by adding an optional checksum value. If the HESC-SER receives a Read command from the Host with the acknowledge set to 0x03 after sending [databyteR high], it will switch to enhanced mode for all future communications. Communication will return to non-checksum mode when the Host CPU sends an acknowledge 0xFF after [databyteR high].

B. Slave Mode:

1. Commands received from the Host and data sent to or received from the to Host CPU over the SerBus. The transaction is invalid and commands/data are not to be used until:

- the final acknowledge 0xFF is received
- the checksum matches the transmitted data (checksum is optional, but if sent must be used)

2. Note: Read and Write is defined as the action the command places on the HESC-SER RAM and EEprom. Therefore, Read and Write have the same meaning for Master and Slave modes:

3a. Write command without checksum acknowledge.

```
HOST: <addressW>      <command>      <databyteW low >      <databyteW high >
HESC-SER:      [0x00]      [0x01]      [0x02]      [0xFF]
```

3b. Write command with checksum acknowledge.

```
HOST: <addressW>      <command>      <databyteW low >      <databyteW high >      <checksum>
HESC-SER:      [0x00]      [0x01]      [0x02]      [0x03]      [0xFF]
```

3c. Write command without checksum acknowledge and without bus timer enabled.

```
HOST: <addressW> <command> <databyteW low > <databyteW high >
HESC-SER:      [0x00]** [0x01]** [0x02]** [0xFF]**
```

4a. Read command without checksum acknowledge.

```
HOST: <addressR>      <command>      <0x02>      <0xFF>
HESC-SER:      [0x00]      [databyteR low]      [databyteR high]
```

4b. Read command with checksum acknowledge.

```
HOST: <addressR>      <command>      <0x02>      <0x03>      <0xFF>
HESC-SER:      [0x00]      [databyteR low]      [databyteR high]      [checksum]
```

4c. Read command without checksum acknowledge and without bus timer enabled.

```
HOST: <addressR> <command>
HESC-SER:      [0x00]** [databyteR low] [databyteR high]
**{HOST does not need to wait for Ack from HESC-SER}
```

where "host" addressW = 0001 001 + 0 (R/W bit) = 0x12
 "host" addressR = 0001 001 + 1 (R/W bit) = 0x13

The checksum is a two digit hexadecimal checksum that is the two's complement of the sum of all preceding bytes. For example the data <0x10> <0x12> <0xC0> <0x03> has the checksum 0x1B.

Section 4 : HESC104 PC/104 Bus Communications

A. Description:

The HESC104 communicates with the Host through the PC/104 bus. Commands and data are sent and received using a 8 bit, I/O memory mapped I/O address. The address lines A0 to A9, & AEN are decoded to provide four addresses that are jumper selectable. An I/O write to the decoded address will "strobe" the data into the HESC, and an I/O read will read the data from the HESC104. Whenever the HESC104 has data in it's output port that requires the Host CPU to perform an I/O read, it generates a PC/104 bus interrupt (IRQ5 or IRQ7, see section on setting jumpers). The PC/104 bus interrupt is removed after an I/O read from the HESC104. The HESC104 operates in a "slave" mode where the Host initiates all the communications between the HESC104 and the Host.

- Table 1 lists the commands the HESC supports.

To ensure reliable communication, an acknowledge byte is returned after each address, command or data byte transmitted. The receiving device (HESC104 or Host) must acknowledge receipt of each byte. This is true even if the bus timer is turned off. (*The HESC104 and HESC-SER differ in that if the HESC-SER bus timer is off an acknowledge byte is not issued.*) If an acknowledge byte doesn't match the acknowledge number expected then a "collision" is deemed to have occurred. The transaction is aborted immediately and the result byte set accordingly.

An "enhanced" communication mode is available by adding an optional checksum value. If the HESC104 receives a Read command from the Host with the acknowledge set to 0x03 after sending [databyteR high], it will switch to enhanced mode for all future communications. Communication will return to non-checksum mode when the Host CPU sends an acknowledge 0xFF after [databyteR high].

B. Slave Mode:

1. Commands received from the Host and data sent to or received from the to Host CPU over the PC/104 bus. The transaction is invalid and commands/data are not to be used until:

- the final acknowledge 0xFF is received
- the checksum matches the transmitted data (checksum is optional, but if sent must be used)

2. Note: Read and Write is defined as the action the command places on the HESC104's RAM and EEprom. Therefore, Read and Write have the same meaning for Master and Slave modes:

3a. Write command without checksum acknowledge.

HOST: <addressW> <command> <databyteW low > <databyteW high >
 HESC104: [0x00] [0x01] [0x02] [0xFF]

3b. Write command with checksum acknowledge.

HOST: <addressW> <command> <databyteW low > <databyteW high > <checksum>
 HESC104: [0x00] [0x01] [0x02] [0x03] [0xFF]

4a. Read command without checksum acknowledge.

HOST: <addressR> <command> <0x02> <0xFF>
 HESC104: [0x00] [databyteR low] [databyteR high]

4b. Read command with checksum acknowledge.

HOST: <addressR> <command> <0x02> <0x03> <0xFF>



HESC104: [0x00] [databyteR low] [databyteR high] [checksum]

where "host" addressW = 0001 001 + 0 (R/W bit) = 0x12
 "host" addressR = 0001 001 + 1 (R/W bit) = 0x13

The checksum is a two digit hexadecimal checksum that is the two's complement of the sum of all preceding bytes. For example the data <0x10> <0x12> <0xC0> <0x03> has the checksum 0x1B.

Section 5 : HESC I²C/SMBus Bus Communications

A. Description:

The HESC can communicate with System Management Bus (SMBus) batteries, I²C digital temperature sensors, and Hosts and microprocessors through the I²C/SMBus. The SMBus is a two-wire interface through which the HESC can communicate to I²C/SMBus devices. The HESC supports I²C/SMBus multi-master bus capability, meaning that other devices capable of controlling the bus can be connected to it. The HESC transfers data by one I²C/SMBus device acting as a master, and another I²C/SMBus device acting as a slave (with one of the devices being the HESC). A master device initiates a bus transfer and provides the clock signals (SCL). A slave device can receive data (SDA) provided by the master or it can provide data to the master. Since more than one device may attempt to take control of the bus as a master, I²C/SMBus provides an arbitration mechanism, relying on the wired-AND connection of all I²C/SMBus interfaces to the I²C/SMBus.

NOTE: Care should be taken in the design of both the input and output stages of SMBus devices, in order not to load the bus when their power plane is turned off.

The HESC uses the master to alert the Host of a change in status or of alarm in the HESC. The HESC alerts the Host by sending the ChargerStatus() value. This occurs when main power is applied or removed, battery pack inserted/removed, battery fully charged or fully discharge, shutdown activated or de-activated, or temperature alarm. When the HESC alerts the Host, the HESC places its address 0x12 in the command byte. The HESC alert communications format would then appear as 0x10, 0x12, datalow, datahigh.

- Table 1 lists the commands the HESC I²C/SMBus supports.

To ensure reliable communication, an acknowledge bit is returned after each address, command or data byte transmitted. The receiving device must acknowledge receipt of each byte. If an acknowledge bit is not received then the transfer is aborted immediately and the result byte set accordingly.

Section 6 : SerBus, SMBus, and PC/104 Command Functions

A. List of Command Functions

1. The SerBus and PC/104 Bus command functions are similar to many of the SMBus command functions. Where possible, the functions are the same as the SMBus functions. The following table list the HESC command functions, access, units and range of the data.
2. There are two types of command functions, RAM and EEPROM. RAM variables are used to actively monitor and control the HESC. However, RAM is volatile memory and loses its contents on power loss. The EEPROM is used to store setpoints and configuration for the HESC. Separate functions allow easy access to the RAM variables.
3. Since setting up the HESC is only done infrequently, only two commands are provided. Function ActiveEEcmd() sets the location for the next EEPROM read or write, and if the location should auto increment. Function EEPROMcmd() reads or writes the EEPROM location as set by ActiveEEcmd().

Table 1, List of HESC Command Functions

Code	Command Function	SerBus	SMBus	PC/104	Access	Units	Range	Description
0x08	BattTempCmd()	✓	✓	✓	R	0.1K *	0 to 6553.5	Read battery temperature
0x09	BattVCmd()	✓	✓	✓	R	mV	0 to 65535	Read battery voltage
0x0A	BattICmd()	✓	✓	✓	R	mA	0 to 32767 0 to -32768	Read battery current
0x0B	BattIavgCmd()	✓	✓	✓	R	mA	0 to 32767 0 to -32768	Read 1 minute rolling average battery current
0x0F	BattRemCapCmd()	✓	✓	✓	R	mAh or 10mWh **	0 to 65535	Read remaining battery capacity
0x11	ChargerSpecInfoCmd()	✓	✓	✓	R	Bit flags	N/A	Read SMBus specification compatibility
0x12	ChargerModeCmd()	✓	✓	✓	W	Bit flags	N/A	Set Charger Mode
0x13	ChargerStatusCmd()	✓	✓	✓	R	Bit flags	N/A	Read charger status
0x14	ChargingCurrentCmd()	✓	✓	✓	R/W	mA	0 to 65535	Read battery charging current setpoint
0x15	ChargingVoltageCmd()	✓	✓	✓	R/W	mV	0 to 65535	Read battery charging voltage setpoint
0x16	AlarmWarningCmd()	✓	✓	✓	R/W	Bit flags	N/A	Alarm Notification
0x3E	GetVersionCmd()	✓	✓1	✓	R	High/Low byte***	N/A	Read charger firmware revision
0x3F	GetChSerNumCmd()	✓	✓1	✓	R	8 byte	N/A	Read charger serial number
0x80	GetI2CtempCmd0()	✓	✓2	✓	R	0.1K *	0 to 6553.5	Read I2C temperature
to								
0x8F	GetI2CtempCmd15()	✓	✓2	✓	R	0.1K *	0 to 6553.5	Read I2C temperature
0x90	TempThCmd()	✓	✓2	✓	R	Word	0 to 65535	Read TH (thermistor) value
0x91	MainVCmd()	✓	✓2	✓	R	mV	0 to 65535	Read main input voltage
0x92	MainICmd()	+	✓2	✓	R	mA	0 to 65535	Read input current
		✓						
0x93	InputPwrCmd()	✓	✓2	✓	R	10mW	0 to 65535	Read input power
0x94	BattPwrCmd()	✓	✓2	✓	R	10mW	0 to 65535	Read charging power
0x95	ChCycleCmd()	✓	✓2	✓	R/W	integer	0 to 3	Read/Set charging cycle
0x96	ChTermLastCmd()	✓	✓2	✓	R	Bitflags	N/A	Read last termination method
0x97	ShutDownCmd()	✓	✓2	✓	R/W	sec	0 to 65535	A write will shut down the power supply in X seconds. A read will return time left until shutdown. Use command PowerSupplyStatusCmd() to determine if a shutdown is in progress.
0x98	PowerSupplyStatusCmd()	✓	✓2	✓	R/W	Bitflags	N/A	Read/Write power supply flags
0x99	SDSUCauseCmd()	✓	✓2	✓	R	Bitflags	N/A	Read cause of SD and SU requests
0x9A	I2CLowAlarmsCmd	✓	✓2	✓	R	Bitflags	N/A	
0x9B	I2CHighAlarmsCmd	✓	✓2	✓	R	Bitflags	N/A	
0xA0	ActiveEEcmd()	✓	✓2	✓	R/W	byte.byte	****	Read/Set active EEprom location and auto increment
0xA1	EEPromCmd()	✓	✓2	✓	R/W	Word	0 to 65535	Read/Write value to active EEprom location

✓1 SMBus Optional Manufacturer Functions

✓2 Function not defined by SMBus standards

* 0 degree Kelvin = -273.2C

** The BattRemCapCmd() capacity value is expressed in either current (mAh at a C/5 discharge rate) or power (10mWh at a P/5 discharge rate) depending on the setting of the capacity mode bit.

*** High byte = major version, Low byte = minor version

**** Low byte = location 0 to 127, High byte: no auto increment = 0; auto increment = 1

B. HESC Function Command Details

1. BattTempCmd() 0x08

Description:

Returns the batteries internal temperature (°K). The actual operational temperature range will typically be in the range of -20°C to +75°C.

Purpose:

The BattTempCmd() function provides accurate cell temperatures for use by HESC and Host management system. The HESC is able to use the temperature as a safety check and the Host may use the temperature for thermal management. (Kelvin units are used to facilitate simple unsigned handling of temperature information and to permit easy conversion to other units.)

Protocol: Read Word

Range: 0 to +6553.5°K -- cell temperature in tenth degree Kelvin (0.1°K) increments

2. BattVCmd() 0x09

Description:

Returns the battery voltage.

Purpose:

The BattVCmd() function provides the Host power management system with an accurate battery voltage. The Host management system can use this voltage, along with battery current information to help enable intelligent, adaptive power management systems.

Protocol: Read Word

Range: 0 to 65,535 mV -- battery voltage measured at HESC terminals in mV increments.

3. BattICmd() 0x0A

Description:

Returns the current being supplied (or accepted) through the HESC.

Purpose:

The BattICmd() function provides a snapshot for the Host power management system of the current flowing into or out of the battery. This information will be of particular use in the Host power management system because it can characterize individual devices and "tune" their operation to actual system power behavior.

Protocol: Read Word

Range: -32,768 to 32,767mA – in mA increments (0 to -32,768 mA for discharge or 1 to 32,767 mA for charge).

4. BattIavgCmd() 0x0B

Description:

Returns a one-minute rolling average based on the current being supplied (or accepted) through the battery.

Purpose:

The BattIavgCmd() function provides the average current flowing into or out of the battery for the Host power management system.

Protocol: Read Word

Range: -32,768 to 32,767mA – in mA increments (0 to -32,768 mA for discharge or 1 to 32,767 mA for charge).

5. BattRemCapCmd() 0x0F

Description:

Returns the predicted remaining battery capacity. The BattRemCapCmd() capacity value is expressed in current.

Purpose:

The BattRemCapCmd() function returns the battery's remaining capacity.

Protocol: Read/Write Word

Range: 0 to 65,5535 x 10mWh -- remaining charge in 10mWh increments

6. ChargerSpecInfoCmd() 0x11

Description:

The Host uses this command to read the charger's extended status bits.

Purpose:

Allows the Host to determine the specification revision the charger supports as well as other extended status information.

Protocol: Read Word

Range: 16-bit word - bit mapped – see Table 2,.

Table 2, ChargerSpecInfoCmd bit map

Bit#	Field	Description
0...3	CHARGER_SPEC	The ChargerSpecInfoCmd() reports the version of the Smart Battery Charger specification the HESC charger supports. All other values reserved. 0001 – Version 1.0 0010 – Version 1.1 0011 – Version 1.1
4...15	Reserved	These bits are reserved and will return zero.

7. ChargerModeCmd() 0x12

Description:

The Host uses this command to set the various charger modes.

Purpose:

Allows the System Host to configure the charger and change the default modes. The default values are set to allow an SMBus Battery and the HESC to work in concert without requiring a host. This is a write only function, but the value of the "mode" bits: INHIBIT_CHARGE and ENABLE_POLLING may be determined using the ChargerStatusCmd() function. Reading will return undefined values.

Protocol: Write Word

Range: 16-bit word - bit mapped - see Table 3,.

Table 3, ChargerModeCmd bit map

Bit#	Field	Description
0	INHIBIT_CHARGE	0 - enable charging (power-on default) 1 - inhibit charging
1	ENABLE_POLLING	0 - disable polling (power-on default for Level 2 chargers) 1 - enable polling (power-on default for Level 3 Smart Battery Chargers)
2	POR_RESET	0 - mode unchanged (default) 1 - set charger to power-on defaults
3	RESET_TO_ZERO	0 - charging values unchanged (default) 1 - set charging values to zero
4...15	Reserved	These bits are reserved and will return zero.

The INHIBIT_CHARGE bit allows charging to be inhibited without changing the ChargingCurrentCmd() and ChargingVoltageCmd() values. Only the Host may set this bit while a battery is charging to inhibit charge. The Smart Battery is not allowed to write to this bit. The charging may be resumed by clearing the bit. This bit is automatically cleared when power is re-applied or when a battery is re-inserted.

The ENABLE_POLLING bit enables the polling feature of the HESC in Level 3 Smart SMBus mode. This bit is set at power on for the HESC.

The POR_RESET bit sets the HESC to its power-on default conditions.

The RESET_TO_ZERO bit sets the ChargingCurrentCmd() and ChargingVoltageCmd() values to zero. This function ALWAYS clears the ChargingVoltageCmd() and ChargingCurrentCmd() values to zero even if the INHIBIT_CHARGE bit is set.

8. ChargerStatusCmd() 0x13

Description:

The Host uses this command to read the HESC charger status bits.

Purpose:

Allows the Host to determine the status of the SMBus safety signal, thermistor or temperature sensor, HESC charger status and SMBus level compatibility of the HESC charger. ChargerStatusCmd() function is used by the power management system to get alarm and status bits, as well as error codes from the HESC. It is also used by the HESC in Master Mode to alert the Host of a change in status or an alarm in the HESC. When the HESC sends the ChargerStatusCmd() to the Host CPU under Master Mode, the communications format is: <0x10>, <0x12>, <datalow>, <datahigh>. This allows the Host to identify the source of the data, and to interpret it correctly.

Protocol: Read Word

Range: 16-bit word - bit mapped - see Table 4,.

Table 4, ChargerStatusCmd bit map

Bit#	Field	Allowable Values
0	CHARGE_INHIBITED	0 - charger is enabled 1 - charger is inhibited
1	POLLING_ENABLED	0 - charger is in slave-mode (polling disabled) 1 - charger is in master-mode (polling enabled)
2	VOLTAGE_NOTREG	0 - charger's output voltage is in regulation 1 - requested ChargingVoltage() is not being met
3	CURRENT_NOTREG	0 - charger's output current is in regulation 1 - requested ChargingCurrent() is not being met
4	LEVEL_2	00 is reserved 01 - charger is a Level 2
5	LEVEL_3	10 - reserved 11 - charger is a Level 3
6	CURRENT_OR	0 - ChargingCurrent() value is valid 1 - ChargingCurrent() value is invalid
7	VOLTAGE_OR	0 - ChargingVoltage() value is valid 1 - ChargingVoltage() value is invalid
8	RES_OR	0 - Safety Signal not over-range 1 - Safety Signal over-range
9	RES_COLD	0 - Safety Signal not cold 1 - Safety Signal cold
10	RES_HOT	0 - Safety Signal not hot 1 - Safety Signal hot
11	RES_UR	0 - Safety Signal not under-range 1 - Safety Signal under-range
12	ALARM_INHIBITED	0 - charger not alarm inhibited 1 - charger alarm inhibited
13	POWER_FAIL	0 - input voltage is not low 1 - input voltage is low
14	BATTERY_PRESENT	0 - battery is not present 1 - battery is present
15	AC_PRESENT	0 - charge power is not available 1 - charge power is available

CHARGE_INHIBITED bit reflects the status of the HESC charger set by the INHIBIT_CHARGE bit.

POLLING_ENABLED bit is set/reset in the HESC charger with the ENABLE_POLLING bit of ChargerModeCmd() set.

VOLTAGE_NOTREG bit is set when the HESC detects that the requested voltage in the ChargingVoltageCmd() register is not in regulation. The VOLTAGE_NOTREG bit typically is set during constant current charging unless the battery voltage reaches the value set in ChargingVoltageCmd() and the HESC begins to voltage regulate to ChargingVoltageCmd() value. VOLTAGE_NOTREG is cleared when the HESC is regulating to the ChargingVoltageCmd() value. VOLTAGE_NOTREG is not defined when the charger is disabled.

CURRENT_NOTREG bit is set when the HESC detects that the requested current in the ChargingCurrentCmd() register is not in regulation. The CURRENT_NOTREG bit will typically be set during constant voltage charging unless the battery current is near the value set in ChargingCurrentCmd() and the HESC begins to current regulate to ChargingCurrentCmd() value. CURRENT_NOTREG is cleared when the HESC is regulating to the ChargingCurrentCmd() value. CURRENT_NOTREG is not defined when the HESC is disabled.

LEVEL_2 bit is defined to always be set.

LEVEL_3 bit is set. The HESC is a Level 3 Smart Battery Charger. Note: The HESC operates as a LEVEL_2 charger when the ENABLE_POLLING bit is cleared.

CURRENT_OR bit is set only when ChargingCurrentCmd() is set to a value outside the current regulation range of the HESC. When ChargingCurrentCmd() is set to the programmatic maximum current + 1mA or more, the CURRENT_OR bit will be set.

VOLTAGE_OR bit is set only when ChargingVoltageCmd() is set to a value outside the voltage regulation range of the HESC. When ChargingVoltageCmd() is set to the programmatic maximum voltage + 1mV or more, the VOLTAGE_OR bit will be set.

RES_OR bit is set when the Th (Safety Signal) resistance value is > 95k ohms. The HESC considers the Th signal as an open circuit.

RES_COLD bit is set when the Th (Safety Signal) resistance value is > 28,500 ohms. The Th signal indicates a cold battery.

RES_HOT bit is set when the Th (Safety Signal) resistance value is < 3150 ohms, which indicates a hot battery.

RES_UR bit is set when the Th (Safety Signal) resistance value is < 575 ohms.

Notes:

- Multiple bits may be set depending on the value of the Th (Safety Signal) (e.g., a Th signal resistance that is 400 ohms will cause both the RES_HOT *and* the RES_UR bits to be set).
- A Smart Battery can signal some or all of the Safety Signal ranges using fixed value resistors. In battery packs that do not require the Safety Signal as a secondary fail-safe indicator, a single, fixed resistor, may be used to select the Safety Signal range, which allows indefinite "wake-up" charging or "wake-up" charging only for the time-out period.
- In all cases, it is the responsibility of the battery pack to manipulate the Safety Signal to obtain correct charger behavior.

ALARM_INHIBITED bit is set if a valid AlarmWarningCmd() message has been received and charging is inhibited as a result. This bit is cleared if both ChargingVoltageCmd() and ChargingCurrentCmd() are re-written to the charger, power is removed, or if a battery is removed.

POWER_FAIL bit is set if the input is below the set threshold.

BATTERY_PRESENT is set if a battery is present, otherwise it is cleared.

AC_PRESENT is set if a source of power for charging is available, otherwise it is cleared.

9. ChargingCurrentCmd() 0x14

Description:

The Host sends the desired charging rate or reads the charging current setpoint.

Purpose:

The HESC uses the ChargingCurrentCmd() function to establish the charging current. In combination with the ChargingVoltageCmd() function and the battery's internal impedance, this function determines the HESC's operating point. Together, these functions permit the HESC to dynamically adjust its charging profile (current/voltage) for optimal charge. The Host can effectively turn off the HESC by returning 0 for this function. The HESC can be operated as a constant voltage source by returning a ChargingCurrentCmd() value of 65535.

Protocol: Read/Write Word

10. ChargingVoltageCmd() 0x15

Description:

The Host sends the desired charging voltage or reads the charging voltage setpoint.

Purpose:

The HESC uses the ChargingVoltageCmd() function to establish the charging voltage. In combination with the ChargingCurrentCmd() function and the battery's internal impedance, this function determines the HESC's operating point. Together, these functions permit the HESC to dynamically adjust its charging profile (current/voltage) for optimal charge. The Host can effectively turn off the HESC by returning 0 for this function. The HESC can be operated as a constant current source by returning a ChargingVoltageCmd() value of 65535.

Protocol: Read/Write Word

Range: 0 to 65,535 mV – charger output voltage set point in mV increments.

11. AlarmWarningCmd() 0x16

Description:

If an SMBus Battery is connected to the HESC, AlarmWarningCmd() is used by the SMBus battery to notify the HESC that one or more alarm conditions exist. Alarm and status indications are encoded as bit fields. If the HESC is charging a Standard Battery pack, it will set the appropriate fields based on the thermistor or digital temperature sensor.

Purpose:

The AlarmWarningCmd() function is used by the power management system to get alarm and status bits, as well as error codes from the HESC.

Protocol: Read Word

Output: 16-bit word - bit mapped - Status Register with alarm conditions bit mapped as in Table 5,:

Table 5, AlarmWarningCmd bit map

Bit#	Field
0	Reserved
1	Reserved
2	Reserved
3	Reserved
4	FULLY_DISCHARGED
5	FULLY_CHARGED
6	DISCHARGING
7	INITIALIZED
8	REMAINING_TIME_ALARM
9	REMAINING_CAPACITY_ALARM
10	Reserved
11	TERMINATE_DISCHARGE_ALARM
12	OVER_TEMP_ALARM
13	Reserved
14	TERMINATE_CHARGE_ALARM
15	OVER_CHARGED_ALARM

12. GetVersionCmd() (0x3E)

Description:

This function returns the firmware version number of the HESC.

Purpose:

The GetVersionCmd() function is used to identify a particular firmware version in the HESC . This may be important in systems that take advantage of enhanced or custom features of a particular HESC revision.

Protocol: Read Word

Output: High byte - major revision
Low byte - minor revision

13. SerialNumber() (0x3F)

Description:

This function returns the serial number of the HESC and the model name. For the HESC-SER models, "HESC-SER" is returned, and for the HESC104 models, "HESC104 " is returned. The eight digit serial number is appended to the end of the model name.

Purpose:

The SerialNumber() function identifies a particular HESC.

Protocol: Read Block

Output: string – Eight character string of the model name followed by an eight character string of the serial number.

14. GetI2CTempCmd0() (0x80) to GetI2CTempCmd15() (0x8F)

Description:

The HESC returns the requested I2C temperature to the Host CPU.

Purpose:

The Host can perform power management and control functions with this information. Remote cooling fans or heaters can be started if temperatures exceed safe limits. Temperature is a primary charging termination for NiCd and NiMh batteries. The HESC supports both digital I2C sensors and thermistors, and either may be used for battery temperature monitoring.

Protocol: Read Word

Range: 0 to 65,535 x 0.1°K – temperature in 0.1K increments (Kelvin: 0 degC = 273.2°K).

15. TempThCmd() (0x90)

Description:

The HESC returns the thermistor value to the Host CPU.

Purpose:

The thermistor monitors the battery temperature, and for the SMBus is a secondary safety device. Temperature is a primary charging termination for NiCd and NiMh batteries. The HESC supports both digital I2C sensors and thermistors, and either may be used for battery temperature monitoring. The Host CPU may use this information to determine the HESC and battery performance.

Protocol: Read Word

Range: 0 to 65,535 – value from ADC converter.

16. MainVCmd() (0x91)

Description:

Returns the Main Input voltage.

Purpose:

The MainVCmd() function provides the Host power management system with an accurate measure of main input voltage. The HESC compares this value with the value of BattVCmd() to determine if power is supplied from the Main Input or the Battery Input supplies.

Protocol: Read Word

Range: 0 to 65,535 mV – main input voltage in mV increments.

17. MainICmd() (0x92)

Description:

Returns the current being supplied to the HESC.

Purpose:

The MainICmd() function provides the Host power management system an accurate measure of the current flowing into the HESC. The current being report by the MainICmd() will be zero if BattVCmd() is greater than MainVCmd().

Protocol: Read Word

Range: 0 to 65,535 mA – input current rate in mA increments

18. InputPwrCmd() (0x93)

Description:

Returns the power being supplied to the HESC.

Purpose:

The InputPwrCmd() function provides a measure of the power flowing into the HESC. The power being reported by the InputPwrCmd() will be from the values of MainVCmd() and MainICmd(), or zero if BattVCmd() > MainVCmd().

Protocol: Read Word

Range: 0 to 65,535 x 10mW – input power in 10mW increments.

19. BattPwrCmd() (0x94)

Description:

Returns the power being charged/discharged to the battery through the HESC.

Purpose:

The BattPwrCmd() function provides the Host power management system a measure of the power charging/discharging into the battery through the HESC. The power being reported by the BattPwrCmd() will be positive for charging, and negative for discharging.

Protocol: Read Word

Range: -32,768 to 32,767 x 10mW – in 10mW increments (0 to -32,768 x 10mW for discharge or 1 to 32,767 x 10mW for charge).

20. ChCycleCmd() (0x95)

Description:

Sets or returns the current charging cycle of the HESC.

Purpose:

The ChCycleCmd() function allows the Host power management system to detect or change the current charge cycle. The Host CPU chooses to do this to minimize input power, or place the battery pack into a different charge cycle.

Protocol: Read/Write Word

Range: 0 to 3 – charge cycle

21. ChTermLastCmd() (0x96)

Description:

This function returns the cause of the last charge termination method for Standard Battery packs.

Purpose:

The Host can determine how effective the charging parameters are by the ChTermLastCmd() for an individual battery. The ChTermLastCmd() will also allow the Host to determine the condition of the battery.

Protocol: 16-bit word - bit mapped – Charge termination bits flags per Table 6,.

Table 6, ChTermLastCmd bit map

Bit#	Bit Name	Description
0	TimeMaxEn	Charging time exceeded TimeMaxDef minutes.
1	BattTempMaxEn	Battery temperature was above the BattTempMaxDef 0.1K.
2	BattIminEn	Charging current was below BattIminDef mA.
3	BattVmaxEn	Charging voltage was above the BattVmaxDef mV.
4	BattVmaxTimeEn	The battery voltage did not increase for BattVmaxTimeDef minutes.
5	BattVdeltaEn	The battery voltage decreased by BattVdeltaDef mV.
6	BattTempRateEn	The temperature increased at a rate of BattTempRateDef 0.1K/minute or greater.
7 to 15	future	

22. ShutDownCmd() (0x97)

Description:

Shut down the HESC outputs in “X” seconds.

Purpose:

Allows the Host CPU to command the HESC to turn off its outputs after a delay. Typically, the Host CPU would use this after executing an ordering shutdown of its files and operating system.

A read using ShutDownCmd() will return the number of seconds until the HESC outputs are turned off. If a shutdown is not in-progress, the ShutDownCmd() will return 0xFFFF.

The default EEprom value [Cmd98SDDef](#) acts as a maximum limit ShutDownCmd() can request for a shutdown time. If ShutDownCmd() requests a shutdown greater than [Cmd98SDDef](#), the value in [Cmd98SDDef](#) will be used.

A write with value equal to zero results in the shortest shut down. ShutDownCmd() does not over-right the EEprom default values

Protocol: Write/Read Word

Range: 0 to 65,535 sec – shut down time in seconds

23. PowerSupplyStatusCmd() (0x98)

Description:

The Host uses this command to read or set the various power supply modes.

Purpose:

Allows the System Host to configure the power supply and change the default modes.

Protocol: Write Word

Range: 16-bit word - bit mapped - see Table 7,.

Table 7, PowerSupplyStatusCmd bit map

Bit#	Bit Name	Description
0	BattAutoStartEn*	Charging is to auto start when the HESC is reset, main power is removed then re-applied, or when a new battery is inserted. 1 = enable, 0 = disable
1	TermEn*	Charge termination is enabled when TermEn is set. 1 = enable, 0 = disable
2	SMBActiveEn	The HESC to function as a level 3 SMBus charger. 1 = enable, 0 = disable
3	IgnHiOffEn	When IgnHiOff is set, the HESC-SER will begin shutdown procedures when the Ign pin is high. If IgnHiOff is low, the HESC-SER will begin shutdown procedures when the Ign pin is low. The shutdown procedure will finish once shutdown is started.
4	BattIsolateEn*	The HESC de-activates the battery enable line (BE) after the power supply enters the shutdown mode.
5	SDserHiLo	Define polarity of SD (shut down) line on RS232 connector SDser = 0; SD RS232 input transitioning from +5V to -5V generates shut down request. SDser = 1; SD RS232 input transitioning from -5V to +5V generates shut down request.
6	Then*	Thermistor monitoring select, 1 = enable, 0 = disable
7	SU_Req	Start up request is registered or active. Uses the Cmd98SUDef for start-up timer interval
8	SD_Req	Shut down request is active. Uses the value Cmd98SDDef for shutdown time interval
9	I2ClowAlarm	A I2C sensor/controller is in low alarm = 1, normal = 0
10	I2ChighAlarm	A I2C sensor/controller is in high alarm = 1, normal = 0
11	IGNinput	Status of ignition input
12	Sdinput	Status of Shut Down input
13	Chen	Charger is enabled and ready to charge (read only)
14	LowBattCap	Outputs cannot turn-on due to Low battery voltage or low battery capacity condition (read only)
15	ChecksumEn	Checksum protocol in effect on SerBus or PC/104 bus

24. SDSUCauseCmd() (0x99)

Description:

The Host uses this command to read the cause(s) of the current SDreq and SUsreq.

Purpose:

Allows the System Host to determine how to adjust shutdown or start-up procedures.

Protocol: Read/Write Word

Range: 16-bit word - bit mapped - see **Error! Reference source not found.**

Table 8, SDSUCauseCmd bit map

Bit#	Action	Bit Name	Cause of Start-Up request
0	SUreq = 1	ChFlags.SUreq	Power applied to HESC with ChFlags.SUreq set
1	SUreq = 1	PowerSupplyStatusCmd (0x98)	Bit 7 set during PowerSupplyStatusCmd write
2	SUreq = 1	IGN-SD	Received a start-up request from the IGN input
3	SUreq = 1	PB-SD	Received a start-up request from the Pushbutton input
4	Not used		
5	Not used		
6	Not used		
7	Not used		

Bit#	Action	Bit Name	Cause of Shut-Down request
8	SDreq = 1	Main Power	Loss of main power
9	SDreq = 1	PowerSupplyStatusCmd (0x98)	Bit 8 set during PowerSupplyStatusCmd write
10	SDreq = 1	IGN-SD	Received a shut-down request from the IGN input
11	SDreq = 1	PB-SD	Received a shut-down request from the Pushbutton input
12	SDreq = 1	ShutDownCmd (0x97)	Command received from Host
13	SDreq = 1	Battery Low	Battery low voltage or battery low capacity
14	Not used		
15	Not used		

25. ActiveEEcmd() (0xA0)

Description:

The Host uses this command to set the address for reading/writing to EEPROM.

Purpose:

Allows setting the EEPROM default change charging profiles and HESC setup. Address must be on even EEPROM address location. The HESC masks off the low address bit to guarantee even address location. The high byte is used to select the auto increment mode.

Protocol: Read/Write Word

Range: Low byte = EEPROM location 0 to 0xFF,
High byte: Bit-0; no auto increment = 0; auto increment = 1.

- See [List of EEPROM Setpoints and Configuration Variable](#)

26. EEPROMCmd () (0xA1)

Description:

The Host uses this command to read/write the data in the EEPROM. The read/write address in the EEPROM will increment after each read/write if the auto increment byte is set = 1 through command function ActiveEEcmd() (0xA0).

Purpose:

Allows the System Host to change HESC default EEPROM profiles.

Protocol: Read/Write Word

Range: 16-bit word. See [List of EEPROM Setpoints and Configuration Variable](#)

Section 7 : EEprom Setpoints and Configuration Variables

A. List of EEprom Setpoints and Configuration Variable

1. The EEprom is used to store setpoints and configuration for the HESC. The EEprom is non-volatile and will not lose its contents on power loss and has an endurance for a minimum of 100,000 cycles of writes or erases
2. Variables or setpoints are stored with their least significant byte stored in the lower memory location, and the most significant byte in the high location.

Table 9, HESC Setpoints and Configuration Variables

EEprom start address				Variable Size	Variable/Setpoint Name	Units	Range	Description
Charge Cycle								
1	2	3	4					
0x00	0x20	0x40	0x60	Word	ChTerm	Bit flags	N/A	Charge termination enable flags
0x02	0x22	0x42	0x62	Word	Future1			
0x04	0x24	0x44	0x64	Word	Future2			
0x06	0x26	0x46	0x66	Word	BattVmaxDef	mV	0 to 65535	Maximum battery charging voltage
0x08	0x28	0x48	0x68	Word	BattVmaxTimeDef	Min	0 to 65535	Maximum time since peak battery voltage detected
0x0A	0x2A	0x4A	0x6A	Word	BattVdeltaDef	mV	0 to 65535	Charge termination negative delta V
0x0C	0x2C	0x4C	0x6C	Word	TimeMaxDef	Min	0 to 65535	Maximum time for charge cycle
0x0E	0x2E	0x4E	0x6E	Word	BattIminDef	mA	0 to 65535	Minimum charge current allowed
0x10	0x30	0x50	0x70	Word	BattImaxDef	mA	0 to 65535	Maximum charge current allowed
0x12	0x32	0x52	0x72	Word	TimeTermEnDef	Min	0 to 65535	Minimum time before charge termination allowed
0x14	0x34	0x54	0x74	Word	BattTempCompDef	mV/degK	0 to 65535	Temperature compensation applied to BattVDef
0x16	0x36	0x56	0x76	Word	BattVDef	mV	0 to 65535	Charging voltage set point
0x18	0x38	0x58	0x78	Word	BattIDef	mA	0 to 65535	Charging current set point
0x1A	0x3A	0x5A	0x7A	Word	BattTempRateDef	0.1K/Min	0 to 6553.5	Maximum rate of battery temperature increase allowed
0x1C	0x3C	0x5C	0x7C	Word	BattTrickleDef	mA	0 to 65535	Trickle charge current if below min temp or voltage
0x1E	0x3E	0x5E	0x7E	Word	BattTrickleTimeDef	Sec	0 to 65535	Maximum time allowed in Trickle charge mode
	0x80			Word	ChFlags	Bit flags	N/A	Charger/power supply enable flags
	0x82			Word	BattLowVoltageDef	mV	0 to 65535	Minimum battery operating voltage
	0x84			Word	BattLowCapacityDef	10mW	0 to 65535	Minimum battery capacity allowed
	0x86			Word	MainPwrMaxDef	10mW	0 to 65535	Maximum input power allowed
	0x88			Byte	MaxBusTime	Timer Ticks	0 to 255	Maximum time before communications timeout
	0x89			Byte	CHCycleMax	Cycle	1 to 4	Defines how many charge cycles to use
	0x8A			Word	BattTempMinDef	0.1K *	0 to 6553.5	Minimum battery charging temperature
	0x8C			Word	BattTempMaxDef	0.1K *	0 to 6553.5	Maximum battery charging temperature
	0x8E			Word	BattVminDef	mV	0 to 65535	Minimum battery charging voltage
	0x90			Byte	ChTempSelect	Bit flags	0 to 16	I2C device to use for battery temp, if zero use Th
	0x91			Byte	ChAmbientSelDef	Bit flags	0 to 16	I2C device to use for ambient temp, if zero use Th
	0x92			Word	I2CpollTimeDef	Sec	0 to 65535	Rate at which I2C devices are polled
	0x94			Word	I2CtsIcenDef	Bit flags	N/A	Enables polling for selected I2C device
	0x96			Word	Future	Bit flags	N/A	
	0x9A							
	0x9C							
	0x9E							

0xA0, 0xA1	I2Cconfig0	Bit flags	N/A	Defines I2C sensor 0 address, and operating modes
0xA2, 0xA3	I2CSetPoint0	0.1K *	0 to 6553.5	I2C Sensor 0 low temp alarm setting
0xA4, 0xA5	I2CHiLoAlarm0	0.1K *	0 to 6553.5	I2C Sensor 0 high temp alarm setting
0xA6, 0xA7	I2Cconfig1	Bit flags	N/A	Defines I2C sensor 1 address, and operating modes
0xA8, 0xA9	I2CSetPoint1	0.1K *	0 to 6553.5	I2C Sensor 1 low temp alarm setting
0xAA, 0xAB	I2CHiLoAlarm1	0.1K *	0 to 6553.5	I2C Sensor 1 high temp alarm setting
0xAC, 0xAD	I2Cconfig2	Bit flags	N/A	Defines I2C sensor 2 address, and operating modes
0xAE, 0xAF	I2CSetPoint2	0.1K *	0 to 6553.5	I2C Sensor 2 low temp alarm setting
0xB0, 0xB1	I2CHiLoAlarm2	0.1K *	0 to 6553.5	I2C Sensor 2 high temp alarm setting
0XB2, 0xB3	I2Cconfig3	Bit flags	N/A	Defines I2C sensor 3 address, and operating modes
0XB4, 0xB5	I2CSetPoint3	0.1K *	0 to 6553.5	I2C Sensor 3 low temp alarm setting
0XB6, 0xB7	I2CHiLoAlarm3	0.1K *	0 to 6553.5	I2C Sensor 3 high temp alarm setting
0XB8, 0xB9	I2Cconfig4	Bit flags	N/A	Defines I2C sensor 4 address, and operating modes
0xBA, 0xBB	I2CSetPoint4	0.1K *	0 to 6553.5	I2C Sensor 4 low temp alarm setting
0xBC, 0xBD	I2CHiLoAlarm4	0.1K *	0 to 6553.5	I2C Sensor 4 high temp alarm setting
0xBE, 0xBF	I2Cconfig5	Bit flags	N/A	Defines I2C sensor 5 address, and operating modes
0xC0, 0xC1	I2CSetPoint5	0.1K *	0 to 6553.5	I2C Sensor 5 low temp alarm setting
0xC2, 0xC3	I2CHiLoAlarm5	0.1K *	0 to 6553.5	I2C Sensor 5 high temp alarm setting
0XC4, 0xC5	I2Cconfig6	Bit flags	N/A	Defines I2C sensor 6 address, and operating modes
0xC6, 0xD7	I2CSetPoint6	0.1K *	0 to 6553.5	I2C Sensor 6 low temp alarm setting
0xC8, 0xD9	I2CHiLoAlarm6	0.1K *	0 to 6553.5	I2C Sensor 6 high temp alarm setting
0xCA, 0xDB	I2Cconfig7	Bit flags	N/A	Defines I2C sensor 7 address, and operating modes
0xCC, 0xCD	I2CSetPoint7	0.1K *	0 to 6553.5	I2C Sensor 7 low temp alarm setting
0xCE, 0xCF	I2CHiLoAlarm7	0.1K *	0 to 6553.5	I2C Sensor 7 high temp alarm setting

0xD0	Word	PWRSDebDef	Sec	0 to 65535	Debounce interval for main power loss
0xD2	Word	PWRSUdebDef	Sec	0 to 65535	Debounce interval for main power applied
0xD4	Word	PWRSDef	Sec	0 to 65535	Shut-Down delay for main power loss
0xD6	Word	PWRSUDef	Sec	0 to 65535	Start-Up delay for main power applied
0xD8	Word	IGNSDebDef	Sec	0 to 65535	Debounce interval for IGN input turned off
0xDA	Word	IGNSUdebDef	Sec	0 to 65535	Debounce interval for IGN input turned on
0xDC	Word	IGNSDef	Sec	0 to 65535	Shut-Down delay for IGN input turned off
0XDE	Word	IGNSUDef	Sec	0 to 65535	Start-Up delay for IGN input turned on
0XE0	Word	PBSDef	Sec	0 to 65535	Shut-Down delay for Pushbutton off
0XE2	Word	PBSUDef	Sec	0 to 65535	Start-Up delay for Pushbutton on
0XE4	Word	BATTSDDef	Sec	0 to 65535	Shut-Down delay for low battery voltage or capacity
0XE6	Word	Cmd98SDDef	Sec	0 to 65535	Shut-Down delay for command PowerSupplyStatusCmd
0XE8	Word	Cmd98SUDef	Sec	0 to 65535	Start-Up delay for command PowerSupplyStatusCmd
0xEA to 0xF7		Future			
0xF8	Word	SDStartupDelayDef	Sec	0 to 65535	Ignore delay of SD request on serial SD line during start-up. (New in 2U28)
0xFA	Word	BattMaxCapDef	10mW	0 to 65535	Maximum Battery Capacity (New in 2U27)
0xFC	Word	BattRemCapDef	10mW	0 to 65535	Remaining Battery Capacity (New in 2U27)
0xFE	Word	BattTime2Recharge	Min	0 to 65535	Minutes from charge termination to start of recharge battery

B. SerBus EEprom Details

1. ChTerm - EEprom Locations 0x00, 0x20, 0x40, 0x60:

Description:

ChTerm is a set of bit flags that enable/disable charging termination and charging functions. Each ChTerm location is active only when its charging cycle is active.

Purpose:

Allow the Host to configure the HESC-SER to charge a particular battery type.

Structure:

Table 10, ChTerm bit map

Bit#	Bit Name	Description
0	BattTempMinEn	Charge termination method that terminates charging if the battery temperature is below the BattTempMinDef. 1 = enable, 0 = disable
1	BattTempMaxEn	Charge termination method that terminates charging if the battery temperature is above the BattTempMaxDef. 1 = enable, 0 = disable
2	BattVminEn	Charge termination method that terminates main charging if the battery voltage is below the BattVminDef. Trickle charging may continue until the Battery voltage reaches BattVminDef. 1 = enable, 0 = disable
3	BattVmaxEn	Charge termination method that terminates charging if the battery voltage is above the BattVmaxDef 1 = enable, 0 = disable
4	BattVmaxTimeEn	Charge termination method that terminates charging if the battery voltage has not increased for BattVmaxTimeDef minutes. 1 = enable, 0 = disable
5	BattVdeltaEn	Charge termination method that terminates charging if the battery voltage has decreased by BattVdeltaDef. 1 = enable, 0 = disable
6	TimeMaxEn	Charge termination method that terminates charging if charging has taken place for TimeMaxDefEn minutes. 1 = enable, 0 = disable
7	BattIminEn	Charge termination method that terminates charging if charging current is below BattIminDef. 1 = enable, 0 = disable
8	TimeTermEn	Prevents charge termination for TimeTermEnDef minutes. 1 = enable, 0 = disable
9	BattTempCompEn	Compensates the BattVDef voltage for the temperature. Compensation is in mV starting at 298.2K (25C). BattVDef decreases when temperature increases above the 298.2K, and increases when the temperature decreases below 298.2K. 1 = enable, 0 = disable
10	BattTempRateEn	Charge termination method that terminates charging if the temperature increases at a rate of BattTempRateDef 0.1K/minute
11	BattTrickleTimeEn	Charge termination method that terminates trickle charging is trickle charging has continued for BattTrickleTimeDef minutes. 1 = enable, 0 = disable
12	Future	
13	Future	
14	Future	
15	Future	

2. Spare - EEprom Locations 0x02 0x22 0x42 0x62

3. Spare - EEprom Locations 0x04 0x24 0x44 0x64

4. BattVmaxDef - EEprom Locations 0x06, 0x26, 0x46, 0x66:

Description:

When BattVmaxEn is enabled, the HESC will terminate charging a standard battery pack when the battery voltage rises above BattVminDef. To enable BattVmaxDef refer ChTermDef.

Purpose:

Prevent damage to batteries that can occur from being overcharged.

Range: 0 to 65,535 mV – voltage in mV increments.

5. BattVmaxTimeDef - EEprom Locations 0x08, 0x28, 0x48, 0x68:

Description:

When BattVmaxTimeEn is enabled, the HESC will terminate charging a standard battery pack when the length of time the HESC has been charging since the last increase in battery voltage exceeds BattVmaxTimeDef minutes. To enable BattVmaxTimeDef refer to ChTermDef.

Purpose:

Prevent damage to batteries that can occur from being overcharged. Some batteries, like NiMh, have a very small negative delta V that may not be detected.

Range: 0 to 65,535 minutes – timing interval in minute increments.

6. BattVdeltaDef - EEprom Locations 0x0A, 0x2A, 0x4A, 0x6A:

Description:

When BattVdeltaEn is enabled, the HESC will terminate charging a standard battery pack when the battery voltage has reduced BattVdeltaDef mV from the maximum peak voltage. To enable BattVdeltaDef refer to ChTermDef.

Purpose:

Prevent damage to batteries that can occur from being overcharged. Some batteries, like NiMh, have a very small negative delta V that may not be detected.

Range: 0 to 65,535 mV – voltage in mV increments.

7. TimeMaxDef - EEprom Locations 0x0C, 0x2C, 0x4C, 0x6C:

Description:

When TimeMaxEn is enabled, the HESC will terminate charging a standard battery pack when the length of time the HESC has been charging (this charge cycle) exceeds TimeMaxDef minutes. To enable TimeMaxDef refer to ChTermDef.

Purpose:

Prevent damage to batteries that can occur from being overcharged. This puts a limit on how long the charger will charge a battery.

Range: 0 to 65,535 minutes – timing interval in minute increments.

8. BattlminDef - EEprom Locations 0x0E, 0x2E, 0x4E, 0x6E:

Description:

When BattlminEn is enabled, the HESC will terminate charging a standard battery pack when the charge current is below BattlminDef.

Purpose:

Prevent damage to batteries that can occur from being low charge currents. Some batteries, like NiMh, should not be charged below a minimum rate or the batteries may overheat.

Range: 0 to 65,535 mA – Current in mA increments.

9. BattlmaxDef - EEprom Locations 0x10, 0x30, 0x50, 0x70:

Description:

When BattlmaxEn is enabled, the HESC will terminate charging a standard battery pack when the charge current exceeds BattlmaxDef. To enable BattlmaxDef refer to ChTermDef.

Purpose:

Prevent damage to batteries that can occur from excessive charge currents. Excessive current can cause serious overheating, and possible venting.

Range: 0 to 65,535 mA – Current in mA increments.

10. TimeTermEnDef - EEprom Locations 0x12, 0x32, 0x52, 0x72:

Description:

When TimeTermEn is enabled, TimeTermEnDef defines the minimum time before charge termination is allowed. Typically set for 2 to 5 minutes. To enable TimeTermEnDef refer to ChTermDef.

Purpose:

Prevent early charge termination due to battery chemistry settling into charge cycle.

Range: 0 to 65,535 minutes – timing interval in minute increments.

11. BattTempCompDef - EEprom Locations 0x14, 0x34, 0x54, 0x74:

Description:

When BattTempCompEn is enabled, the HESC will compensate the charging voltage for every °K above 298.2°K (25°C), the charging voltage is reduced by BattTempCompDef. To enable BattTempCompDef refer to ChTermDef.

Purpose:

Lead Acid batteries typically require a temperature compensation if operating in varying temperature ranges. Without temperature compensation, the electrolyte could be “boiled” away in high ambient temperatures, and not fully charged in low ambient temperatures.

Range: 0 to +65535 mV/°K – Temperature compensation in mV/°K increments.

Example: If BattTempCompDef = 15, and the battery temperature = 308.2°K, BattVDef (charging voltage setpoint) will be reduced by 150mV.

12. BattVDef - EEprom Locations 0x16, 0x36, 0x56, 0x76:

Description:

BattVDef defines the open circuit output voltage of the charger. If the charger is operating in “constant current” mode the output voltage will be less than BattVDef.

Purpose:

Sets the constant voltage charging setpoint.

Range: 0 to 65,535 mV – voltage in mV increments.

Example: The BAT104-NiMh typically has a BattVDef = 12,200 and BattIDef = 1000. Since NiMh batteries are usually charged in constant current mode, the charging voltage is set slightly higher than the maximum expected voltage (maximum expected is 11,200mV) across the battery terminals during charging. Charging current will remain at the one ampere level until the BAT104-NiMh is nearly fully charged, whereupon the charging current will begin to taper off. At this point, charging is normally terminated.

13. BattIDef - EEprom Locations 0x18, 0x38, 0x58, 0x78:

Description:

BattIDef defines the “shourt circuit” output current of the charger. If the charger is operating in “constant voltage” mode the output current will be less than BattIDef.

Purpose:

Sets the constant current charging setpoint.

Range: 0 to 65,535 mA – current in mA increments.

Example: The BAT104-NiMh typically has a BattVDef = 12,200 and BattIDef = 1000. Since NiMh batteries are usually charged in constant current mode, the charging voltage is set slightly higher than the maximum expected voltage (maximum expected is 11,200mV) across the battery terminals during charging. Charging current will remain at the one-ampere level until the BAT104-NiMh is nearly fully charged, whereupon the charging current will begin to taper off. At this point, charging is normally terminated.

14. BattTempRateDef - EEprom Locations 0x1A, 0x3A, 0x5A, 0x7A:

Description:

When BattTempRateEn is enabled, the HESC will terminate charging when the rate of battery temperature increases by more BattTempRateDef. To enable BattTempRateDef refer to ChTermDef.

Purpose:

Prevent damage to batteries that can occur from being overcharged. The rate of battery temperature increase is a primary charge termination for NiCd and NiMh batteries.

Range: 0 to +65,535 x 0.1°K/Min – Rate of temperature in 0.1°K/minute increments.

Example: Typically, BattTempRateDef is set for 5 x 0.1°K/Minute for NiCd and NiMh batteries.

15. BattTrickleDef - EEprom Locations 0x1C, 0x3C, 0x5C, 0x7C:

Description:

Used in the SMBus battery wakeup mode to assist in establishing initial communications with the SMBus battery. When in Trickle charge mode, BattTrickleDef sets the trickle charge current. Only the value in EEprom Location 0x1C is used for SMBus Trickle Charge current setting. (Future uses of the BattTrickleDef values for standard battery packs is being researched).

Purpose:

Used to establish communications with an SMBus battery.

Range: 0 to 65,535 mA – current in mA increments.

Example: A typical setting for waking an SMBus battery is 100mA. Some SMBus may require larger amounts of current.

16. BattTrickleTimeDef - EEprom Locations 0x1E, 0x3E, 0x5E, 0x7E:

Description:

BattTrickleTimeDef is automatically enabled/disabled by the HESC whenever main power is applied or a battery is “inserted” into an SMBus enabled (see ChFlagsDef, SMBActiveEn flag) system. The manual setting of BattTrickleTimeDef EEprom register has no current effect on the operation of the HESC. Future firmware developments may take advantage of this EEprom register setting.

17. ChFlagsDef - EEprom Locations 0x80;

Description:

ChFlags is a set of bit flags that enable/disable charging and power supply functions.

Purpose:

ChFlags allows the Host to configure the HESC-SER to the type of battery pack, and system it is installed into.

Table 11, ChFlags bit map

Bit#	Bit Name	Description
0	BattAutoStartEn*	Charging is to autostart when the HESC-SER is reset, main power is removed then re-applied, or when a new battery is inserted. 1 = enable, 0 = disable
1	TermEn*	Charge termination is enabled when TermEn is set. 1 = enable, 0 = disable
2	SMBActiveEn	The HESC-SER to function as a level 3 SMBus charger. 1 = enable, 0 = disable SMBus timing in effect when SMBActiveEn = 1
3	IgnHiOffEn	When IgnHiOff is set, the HESC-SER will begin shutdown procedures when the IGN pin is high. If IgnHiOff is low, the HESC-SER will begin shutdown procedures when the IGN pin is low. The shutdown procedure will finish once shutdown is started.
4	BattIsolateEn*	The HESC-SER de-activates the battery enable line (BE) after the power supply enters the shutdown mode.
5	SDserHiLo	Define polarity of SD (shut down) line on RS232 connector SDser = 0; SD RS232 input transitioning from +5V to -5V generates shut down request. SDser = 1; SD RS232 input transitioning from -5V to +5V generates shut down request.
6	Then*	Thermistor monitoring select, 1 = enable, 0 = disable
7	SUreq	Startup request when power applied when HESC-SER is hard-off**, 1 = off, 0 = on

- For standard battery packs only (ie. Not for SMBus battery packs)

18. BattLowVoltageDef – EEprom Locations 0x82

Description:

When the battery voltage drops below BattLowVoltageDef a Shutdown is requested if the power supply outputs are energized. The shut down will occur in BATTSDDef seconds. Setting BattLowVoltageDef to zero prevents any possible shut down due to low battery voltage.

Purpose:

Allow time for the Operating System to shut down before the battery is fully discharged or damaged.

Range: 0 to 65,535 mV – voltage in mV increments.

19. BattLowCapacityDef – EEprom Locations 0x84

Description:

When the battery capacity drops below BattLowCapDef a Shutdown is requested if the power supply outputs are energized. The shut down will occur in BATTSDDef seconds. Setting BattLowCapDef to zero prevents any possible shut down due to low battery capacity.

Purpose:

Allow time for the Operating System to shut down before the battery is fully discharged or damaged.

Range: 0 to 65,535 x 10mWh – power in 10mWh increments.

20. MainPwrMaxDef – EEprom Locations 0x86, 0x87

Description:

When the main power exceeds the set limit, the maximum battery charging current is reduced. A setting of zero disables this function.

Purpose:

To prevent overloading of the input supply. Typically, this input supply might be a limited power source such as a wall "cube".

Range: 0 to 65,535 x 10mWh – power in 10mWh increments.

21. MaxBusTimeDef – EEprom Locations 0x88

Description:

Resets the HESC communication (SerBus for RS232 connected HESCs, and PC/104 bus for PC/104 bus connected HESCs) in case of communication error resulting from incomplete communications transaction. Set to value = 0 disables bus timer operation. Normal value for bus timer operation is 255.

Purpose:

Reset HESC communications.

Range: 0 to 255 – no units.

22. CHCycleMaxDef – EEprom Locations 0x89

Description:

CHCycleMaxDef is the number of charge cycles the HESC charger uses in charging the standard (non-SMBus) battery. The HESC uses the charging termination defines from EEprom registers 00 to 7E.

Purpose:

Defines the number of charge cycles to use.

Range: 1 to 4 – no units.

23. BattTempMinDef - EEprom Locations 0x8A:

Description:

When BattTempMinEn is enabled, the HESC will not charge a standard battery pack when the temperature is below BattTempMinDef degrees.

Purpose:

Prevent damage to batteries that can occur when being charged at low temperatures.

Range: 0 to 65,535 x 0.1°K -- cell temperature in tenth degree Kelvin (0.1°K) increments

24. BattTempMaxDef - EEprom Locations 8C:

Description:

When BattTempMaxEn is enabled, the HESC will terminate charging a standard battery pack when the battery temperature rises above BattTempMaxDef degrees.

Purpose:

Prevent damage to batteries that can occur from being over charged or charged at high ambient temperatures.

Range: 0 to 65,535 x 0.1°K -- cell temperature in tenth degree Kelvin (0.1°K) increments

25. BattVminDef - EEprom Locations 0x8E:

Description:

When BattVminEn is enabled, the HESC will not charge or terminate charging a standard battery pack when the battery voltage is below BattVminDef mV.

Purpose:

To prevent damage to batteries that can occur from being charged when in an excessively low charge condition, or to prevent normal charging if one or more cells are faulty.

Range: 0 to 65,535 mV – voltage in mV increments.

26. ChTempSelectDef (0x90)

ChTempSelect selects a temperature sensor for the charging control of the primary battery. The selected sensor is used to report the temperature for BattTempCmd(). Please refer to **Error! Reference source not found.** for configuration of digital temperature devices such as the TS-ICs, and the digital temperature sensors used on the Tri-M battery boards.

Table 12, Temperature device selection values:

Description	Value:
Thermister	0
Temperature Device 0	1
Temperature Device 1	2
Temperature Device 2	3
Temperature Device 3	4
Temperature Device 4	5
Temperature Device 5	6
Temperature Device 6	7
Temperature Device 7	8

Purpose:

Indicates what I2C devices are on the I2C/SMBus to use for the main temperature sensor for battery monitoring and charging.

Range: 0 to 8 – no units.

27. I2CpollTimeDef - EEprom Locations 0x92, 0x93

Description:

Polling timer interval for TS-IC temperature sensors, and RTC support. Typical polling rates are 4 to 10 seconds, although it is possible to use larger or smaller values. Too small a value and the HESC might not be able to complete all the requested polling before the start of the next poll. Too large and the temperature response for charge termination is impeded.

Purpose:

Allows customizing of the scanning of the I2C devices.

Range: 0 to 65,535 seconds.

28. I2CTsICenDef - EEprom Locations 0x94

Description:

I2CTsICenDef is a set of bit flags that indicate what I2C TS-IC or TC-IC devices are connected to the HESC. Up to eight TS-ICs or TC-ICs can be used. Each bit enables a TS-IC or TC-IC. Refer to "[Section 8: Temperature Sensor, TS-IC and Controller, TC-IC](#)" for details on setting up TS-IC and TC-IC devices. Each device is enabled for polling by select respective bit enable.

Table 13, TS-IC and TC-IC device enable settings:

Default EEPROM address 0x94							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Device 7	Device 6	Device 5	Device 4	Device 3	Device 2	Device 1	Device 0

Purpose:

Indicates what I2C devices are on the I2C/SMBus connected to the HESC.

29. PWRSDdebDef (0xD0), PWRSUdebDef (0xD2), IGNSDdebDef (0xD8), IGNSUdebDef (0xDA)

Description:

Defines the timer interval for debouncing signal. Debounce timers include:

- Main power loss.
- Main power restored.
- Ignition switch activated.
- Ignition switch de-activated

Purpose: Prevents unnecessary start-up or shutdown of the Host CPU.

Range: 0 to 65535 seconds. Setting a value equal to zero does **NOT** disable the interval timer.

30. PWRSDDef (0xD4), IGNSDDef (0xDC), PBSDDef (0xE0), BATTSDDef (0xE4), Cmd98SDDef (0xE6)

Description:

Defines the timer interval for initiating a Shutdown. Initiating a Shutdown in the HESC results in the Host CPU being notified of an impending shutdown of the HESC outputs. Possible shutdown causes are:

- Main power loss.
- Ignition switch activated.
- Momentary push-button switch depressed.
- Host CPU, either SER-Bus command or serial port handshake lines.

Purpose: Shutdown timers allow time to close files, and properly stop the operating system.

Range: 0 to 65535 seconds. Setting a value equal to zero disables the timer.

31. PWRSUDef (0xD6), IGNSUDef (0xDE), PBSUDef (0xE2), Cmd98SUDef (0xE8)

Description:

Defines the timer interval for initiating a Start-Up. Possible shutdown causes are:

- Return of Main power.
- Ignition switch de-activated.
- Momentary push-button switch depressed.
- Host CPU, either SER-Bus command or serial port handshake lines.

Purpose: Start-up timers allow the delayed start of the Host CPU to conserve energy.

Range: 0 to 65535 seconds. Setting a value equal to zero disables the timer.

32. SDStartupDelayDef (0xF8), (New in version 2U28)

Description:

- Defines the interval for ignoring a Startdown request from the serial SD line during when the main outputs are turned on (ie Host CPU is booting).
 - Operating systems such as Windows to require time to boot before the serial SD line status is valid.
- SDStartupDelayDef

Purpose: Allows the Host CPU to boot before the serial SD line shut-down requests are accepted.

Range: 0 to 65535 seconds. Setting a value equal to zero reduces the ignore interval to the minimum duration.

33. BattMaxCapDef – EEprom Locations 0xFA, 0xFB (New in version 2U27)

Description:

For standard battery packs (non-SMBus), BattMaxCapDef is required to be set to the capacity of the battery. BattMaxCapDef is used to provide a limit to the value BattRemCapCmd().

Purpose:

To assist in tracking remaining battery capacity. Useful to prevent runaway capacity values as a result of trickle charging.

Range: 0 to 65,535 x 10mWh –capacity in 10mWh increments.

34. BattRemCapDef – EEprom Locations 0xFC, 0xFD (New in version 2U27)

Description:

For standard battery packs (non-SMBus), BattRemCapDef is used to store the value value BattRemCapCmd() into EEprom just before the HESC isolates itself from a battery pack equipped with isolating Mosfet controlled by the BE output signal.

Purpose:

To assist in tracking remaining battery capacity. The HESC loads the value stored in BattRemCapDef when “cold-started” (ie: when power is applied to an HESC that has no main or battery power connected).

Range: 0 to 65,535 x 10mWh –capacity in 10mWh increments.

35. BattTime2RechargeDef - EEprom Locations 0xFE, 0xFF:

Description:

Minutes from last charge termination to start of a recharge battery cycle.

Purpose:

Prevents batteries from self-discharging if HESC has terminated charging for a long time period.

Range: 0 to 65,535 x minutes – delay time in minute increments.

Section 8 : Temperature Sensor, TS-IC and Controller, TC-IC

The HESC can support up to a total of 8 TS-IC sensors and TC-IC controllers on the I2C bus. A block of six EEPROM bytes are reserved for each device. The six EEPROM bytes have the following names and functions:

1. Byte 0 I2Cconfig#
- See table below
2. Byte 1 Address byte#
- Bits 1 to 7 forms the I2C address, bit 0 forms R/W bit. For a read set bit 0 = 1 and for a write set bit 0 = 0.
3. Byte 2 & 3 I2CSetpoint#
For TC-IC: Setpoint value that will be sent. Value = 0 to 65535.
For TS-IC: Low alarm value. Alarm range = 0 to 65535.
4. Byte 4 & 5 I2CHiLoAlarm#.
For TC-IC: Low byte = low alarm value, High byte = high alarm value. Value = 0 to 255.
Low alarm setting = I2CSetpoint# - I2CHiLoAlarm# (low byte).
High alarm setting = I2CSetpoint# + I2CHiLoAlarm#(high byte).
Note: if I2Csetpoint < I2ChiLoAlarm#(low byte), then Low alarm setting = 0;
if I2Csetpoint > (65535 - I2ChiLoAlarm#(high byte)), then High alarm setting = 65535;

For TS-IC: High alarm value. Alarm range = 0 to 65535.

Table 14, Temperature Sensor and Temperature Controller bit map

Bit#	Bit Name	Description
0	Cmd bit 0	Bit 0 and 1 selects data and/or commands within the TC-IC address. Refer to TC-IC for more details.
1	Cmd bit 1	For TS-IC, Cmd bit 0 & 1 should be zero. For a write operation the contents of I2CSetpoint# will be sent as the data. The data returned from a read operation is compared to the alarm settings.
2	MainPwr	Indicates to TC-IC devices that main power is available when = 1. When operating on battery power = 0. Works for read or write to TC-IC devices. This bit is a don't care for TS-ICs.
3	LimitedPwr	Indicates to TC-IC devices that limited power (main or battery) is available. Works for read or write to TC-IC devices. This bit is a don't care for TS-ICs.
4	ShutDown	Indicates to TC-IC devices that the HESC is in timed shutdown mode. HESC outputs will turn off after the timed shutdown finishes. Works for read or write to TC-IC devices. This bit is a don't care for TS-ICs.
5	AlarmLoEn	Enables low alarm reporting = 1, Disables low alarm reporting = 0.
6	AlarmHiEn	Enables high alarm reporting = 1, Disables high alarm reporting = 0;
7	TCICSel	Selects temperature controller (TC-IC) or temperature sensor (TC-IS): For TC-IC set bit to 1, for TS-IC set bit to 0

Note: The "#" represent the number (0 to 15) of the TC-IC or TS-IC device.

Section 9 : Battery Charging Algorithms and Strategies

A. Sealed Lead Acid, SLA

1. Single Stage Charging

Many SLA batteries require only a single stage of charging. In single stage charging, the battery is charged with constant current until the battery voltage approaches the "float" voltage. The float voltage is the voltage across the battery when a small trickle current is used to maintain the full charge state of the SLA battery. The float voltage is very close to the "open circuit" voltage of the HESC charger output, and in most instances, is an acceptable method of checking the HESC float voltage setting. When the battery voltage rises close to the float voltage the charger transitions from constant current to constant voltage charging. The transition from constant current to constant voltage is not an instantaneous change, but gradual as the net potential difference between the HESC charger output and the battery voltage is not sufficient to maintain the current in constant current mode.

The following is an example charging parameters, and charge termination methods that are suitable for SLA batteries requiring single stage charging.

Ex. 12V SLA (6 cell), 4.5amp-hour, ambient temperature conditions -20C to 35C

Table 15, SLA Single Stage Charging Set-up

EEprom Enable Values	EEprom Variable Values	Description
BattTempMaxEn = 1	BattTempMax = 3182*	Terminates charging if battery temperature above BattTempMax. Set for 45C
BattVmaxEn = 1	BattVmax = 13900	Terminates charging if battery voltage above BattVmaxDef. Set for 13.9V
BattTempCompEn = 1	BattTempComp = 18	Compensates the BattVDef voltage for the ambient temperature. Compensation is in mV starting at 298.2K (25C).
N/A	BattVDef = 13700	"Float" voltage set-up. Set for 13.7 volts
N/A	BattIDef = 2500	Maximum charge current. Set for 2500mA
CHCycleMax = 1		Set for single stage charging
BattAutoStartEn = 1		Charging auto starts when the HESC is reset (main power is removed then re-applied), or when a new battery is inserted
TermEn = 1		Charge termination is enabled
BattIsolateEn = 1		HESC de-activates the battery enable line (BE) after the power supply enters the shutdown mode.
Then = 1		Thermistor monitoring enabled

*Temperature in 0.1degK, absolute zero (0K) = -273.2C

2. Dual Stage Charging

A disadvantage of single stage charging is the charging current drops as the battery voltage approaches the float voltage. A two stage charging algorithm maintains full charging current throughout the first stage, and switches to constant float voltage charging in the second stage. The termination of stage 1 charging is when the battery voltage reaches the stage one BattVmax voltage. BattVmax is usually higher than the float voltage (2.45V/cell vs 2.3V/cell). Since the HESC is required to operate in constant current mode throughout stage one, the BattVDef has to be set higher than BattVMax. In theory, BattVDef could be set to its maximum, but this is not a good practice. A better practice is to set BattVDef just high enough to allow the HESC to remain in constant current mode throughout stage one charging.

Table 16, SLA Two Stage Charging Set-up

EEprom Enable Values	EEprom Variable Values	Stage	Description
BattTempMaxEn = 1	BattTempMax = 3182*	1	Terminates charging if battery temperature above BattTempMax. Set for 45C
BattVmaxEn = 1	BattVmax = 14700	1	Terminates charging if battery voltage above BattVmaxDef. Set for 13.9V
BattTempCompEn = 1	BattTempComp = 18	1	Compensates the BattVDef voltage for the ambient temperature. Compensation is in mV starting at 298.2K (25C).
N/A	BattVDef = 15700	1	"Float" voltage set-up. Set for 13.7 volts
N/A	BattIDef = 2500	1	Maximum charge current. Set for 2500mA
BattTempMaxEn = 0	N/A	2	Terminates charging if battery temperature above BattTempMax. Set for 45C
BattVmaxEn = 0	N/A	2	Terminates charging if battery voltage above BattVmaxDef. Set for 13.9V
BattTempCompEn = 1	BattTempComp = 18	2	Compensates the BattVDef voltage for the ambient temperature. Compensation is in mV starting at 298.2K (25C).
N/A	BattVDef = 13700	2	"Float" voltage set-up. Set for 13.7 volts
N/A	BattIDef = 2500	2	Maximum charge current. Set for 2500mA
CHCycleMax = 2			Set for two stage charging
BattAutoStartEn = 1			Charging auto starts when the HESC is reset (main power is removed then re-applied), or when a new battery is inserted
TermEn = 1			Charge termination is enabled
BattIsolateEn = 1			HESC de-activates the battery enable line (BE) after the power supply enters the shutdown mode.
Then = 1			Thermistor monitoring enabled

Section 10 HESC-UPS FIRMWARE UPDATE PROCEDURE

NOTE: The HESC profile should always be updated before HESC-UPS firmware is loaded if the HESC did not have HESC-UPS firmware already loaded. This will load known values into the EEprom and prevent a situation where a default value of 0xFFFF for a start up timer will prevent the HESC outputs from turning on. Should the situation arise where the outputs can't be turned on because of an incorrect value in the HESC EEprom, the HESC can be "hot wired" by connecting +5 volts from another source to the HESC +5 volt output. This will not cause any harm or damage to the HESC.

To update the profile:

1. Connect serial cable between CN9 of HESC-SER and host CPU COM port or plug Host CPU board onto HESC104 PC/104 connector.
2. Apply main power to CN6 of HESC.
3. Start SCU utility on host.
4. Select INIT-SETUP from menu and select AUTO_SELECT; press OK button after HESC is initialized.
5. Select FILE-OPEN from menu and select the file.
6. Select EEPROM from menu and select UPDATE ALL.
7. Select WRITE to update the profile.
8. Close SCU after profile is updated.
9. Remove main power from CN6.

To update the firmware:

1. Connect a wire between SDA (CN5-5 or CN7-4) and ground (CN5-4 or CN7-2) to put the power supply in firmware upgrade mode.
2. Apply main power to CN6.
3. Start SCU utility on host.
4. Select FILE-OPEN from menu and select the firmware file.
5. Select INIT-SETUP and select the following:
 - a. Access Type: Select correct port type and address.
 - b. Protocol: Select "Bus Timer and No Checksum".
 - c. Firmware Type: Select "HESC-UPS".
6. Press OK button after HESC is initialized.
7. Select INIT-FW UPDATE and press the START/STOP UPDATE button.
8. Read the info from the dialog box and then press OK button.
9. Remove the wire connecting CN5-5 and CN5-4 'AFTER' firmware update is started.
10. Close SCU after update is done.
11. Remove main power from CN6.
12. Wait for 30 seconds after power down.
13. Apply main power again.

Section 11 : Implementing a smart “Watchdog Timer” on the Host CPU

A smart watchdog timer can be implemented using a couple of the HESC-UPS commands. If the Host CPU fails to “tickle” the HESC within the watchdog interval, the HESC will turn off the outputs to the Host CPU, then turn the outputs back on resulting in a “cold boot”. The watchdog interval, as well as the interval when the outputs are turned off can be set.

The following steps must be taken to implement the watchdog function.

1. Set the command shut down time interval in the EEPROM profile to a value larger than the required watchdog interval. This interval is in seconds and can have a value up to 65535 seconds and can be set with the SCU.exe utility from Tri-M Engineering.
2. Set the command start up time interval in the EEPROM profile for the Host CPU to remain unpowered before starting up again. This interval is in seconds and can have a value up to 65535 seconds and can be set with the SCU.exe utility from Tri-M Engineering.
3. The Host CPU must continue to issue the two following commands to tickle the HESC at a rate greater than the watchdog interval for normal operation to continue.
 - a. Command ShutDownCmd() with the desired watchdog interval will result in the HESC to initiate it's shutdown process. Any watchdog value larger than the interval set in step one will be changed to the value set in step one.
 - b. Command PowerSupplyStatusCmd() must be issued after the ShutDownCmd() with the shutdown request (SD_Req) flag and the start-up request (SU_Req) flag set. Good programming practice might be to read the PowerSupplyStatusCmd() first; OR the SD_Req and the SU_Req bits to that value; then write this value back to the HESC. The PowerSupplyStatusCmd() must be issued before the value set by the ShutDownCmd() times out or the HESC will shut down and not restart.

Section 12 : LED Operation

1. The HESC-UPS firmware toggles the LED-HB (CPU heart-beat) and the LED-CH (Charger indication) LEDs displaying the current status and operation of the HESC. (Note: The HESC104 does not have an LED-CH LED.)
2. During normal operation (non-firmware upload), the LED-HB toggles continuously. The frequency of the toggling is 1Hz when not in a start-up or shutdown mode. In a Shutdown mode the toggling frequency is 0.5Hz and for a Start-up mode the frequency is 2Hz (Table1).
3. The LED-CH is off when not charging and when charging, the LED-CH toggles. The frequency of the toggling is according to the start-up and shutdown modes (Table 2). When charging is terminated, the LED-CH turns steady on.
4. When both LED-HB and LED-CH are toggling, they toggle opposite to each other.

Description	LED-HB
Normal mode	Toggle @ 1Hz
Shutdown mode	Toggle @ 0.5Hz
Start-up mode	Toggle @ 2Hz

Table 17, Heatbeat LED toggle rates

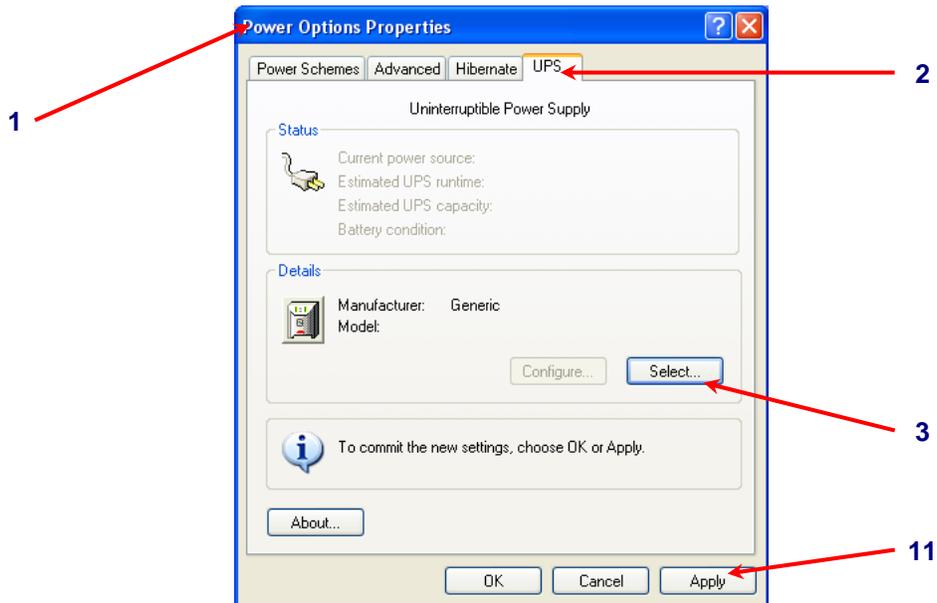
Description	LED-CH
HESC is not in charge mode	Off
HESC is charging in Normal mode	Toggle @ 1Hz
HESC is charging in Shutdown mode	Toggle @ 0.5Hz
HESC is charging in Start-up mode	Toggle @ 2Hz
HESC has terminated charging	Steady on

Table 18, Charger LED operation

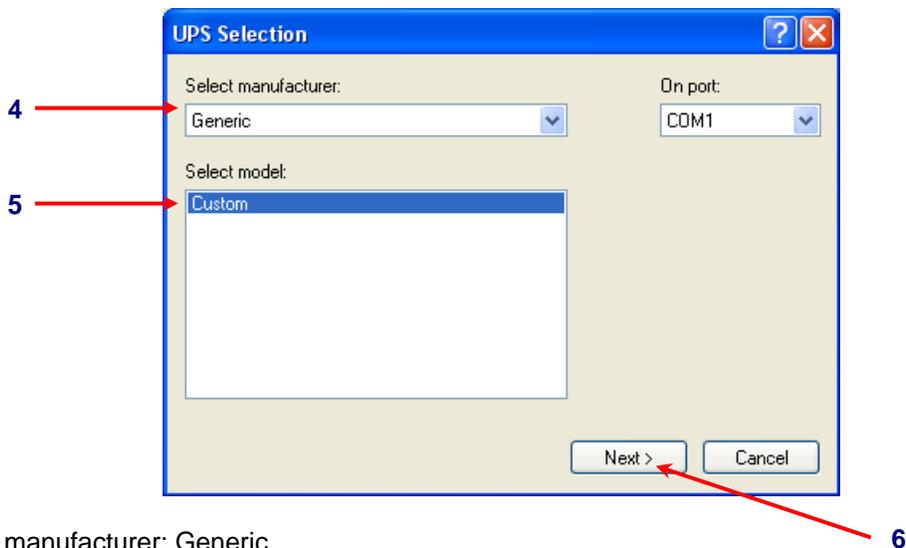
Section 13 : UPS function for Windows compatibility

The following settings allow the UPS function of the power supply to work with Windows 98/2000/XP.

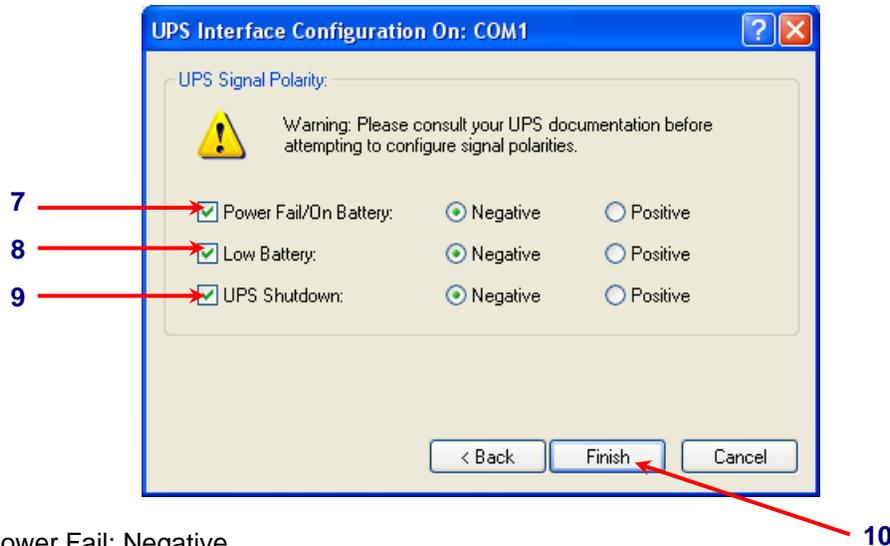
Windows UPS setting



1. Select the Power Options Properties in Control Panel.
2. Select UPS properties.
3. Click 'Select' button

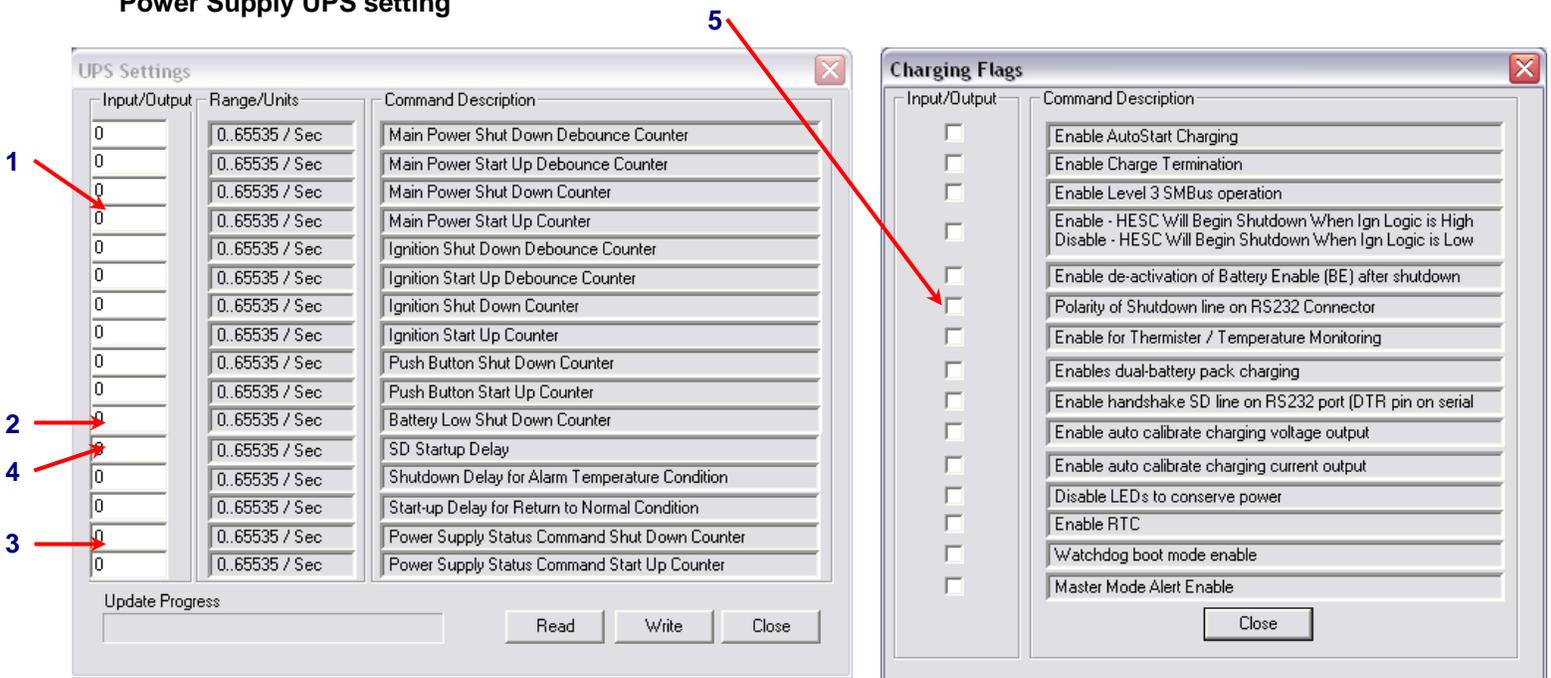


4. Select manufacturer: Generic
5. Select model Custom
6. Click 'Next' button



- 7. Select Power Fail: Negative
- 8. Select Low Battery: Negative
- 9. Select Shutdown: Negative
- 10. Click 'Finish' button
- 11. Click 'OK' button

Power Supply UPS setting



- 1. Set 'Main Power Shutdown counter' to a value bigger than the time required by Windows to shutdown.
- 2. Set 'Battery Low Shutdown counter' to a value bigger than the time required by Windows to shutdown.
- 3. Set 'Power Supply Status Command Shutdown counter' as above.
- 4. Set 'SD Startup Delay' to a value bigger than the time required by Window to boot completely.
- 5. Disable 'Polarity of Shutdown line on RS232 Connector'.