



Smart Charger & Smart Selector Implementation & Safety Issues

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General Safety Devices for Batteries

- Many batteries have
 - Thermostat
 - Thermal fuse
 - Short-circuit protection
- Lithium Ion batteries also have
 - Single-cell disconnects
 - Electronic charge and discharge control

General Safety Devices for Chargers

- Many chargers have
 - AC input fuse
 - Output current safety limit
 - Thermal shutdown devices
- Some chargers also have
 - Fast-charge qualification
 - Minimum voltage
 - Temperature window

General Safety Devices for Chargers (cont'd.)

- Time-limited fast charge
- Fast-charge termination
 - $\Delta T/\Delta t$, maximum temperature
 - $-\Delta V$, peak voltage detection
 - Minimum charging current

General Safety Devices for Battery Selection

- Many selectors have
 - Reverse current flow protection
 - Short-circuit protection
- Most selectors are custom designs

SBS Considerations

- The general safety practices are the same for SBS
- SBS does not limit the additional safety precautions
- Meeting the SMBus and SBData specifications does not guarantee a safe system

Smart Charger Safety Issues

- Battery detection
 - Thermistor present
 - Battery communication
 - Dead battery: Very low voltage or pack protection has disconnected battery
 - Wake-up charge or no communications
 - <100mA
 - Charges for more than 140 but less than 210 seconds
 - Terminates if thermistor is out of range
 - Switches to controlled charge on command

Smart Charger Safety Issues (cont'd.)

- Dead battery safety issues
 - Maximum voltage during wake-up charging
 - Thermistor battery type selection (500 Ω or less wake-up charging is allowed)

Smart Charger Safety Issues (cont'd.)

- Level 2 “controlled” charging
 - Battery broadcast charging voltage and current limits.
 - The charger limits the charging voltage and current to the requested values
 - Accuracy is $\pm 5\%$ of the most significant bit weight
 - The charger may not have the power to meet the -5% specification
 - Loss through the battery contacts and internal circuits may limit the actual voltage

Smart Charger Safety Issues (cont'd.)

- Level 2 “controlled” charging must stop when
 - The charger receives a critical message
 - The charger receives a zero voltage or current limit
 - The thermistor is out of the valid range
 - Charger voltage and current limits message time-out <145 seconds

Thermistor Ranges

| Thermistor | Charger Status Bits | Description | Wake-up Charge | Response to Charging Requests | Notes |
|----------------------|-------------------------|--------------|---|-------------------------------|---|
| 0 to 500 Ω | THERM_UR, THERM_HOT | under-range | allowed for initial time-out period | allowed | Charger can "wake-up" charge for time-out period; controlled charge allowed. |
| 500 to 3k Ω | THERM_HOT | hot | not allowed | not allowed | Fail-safe charge termination—charger must not supply current |
| 3k to 30k Ω | (none) | normal range | allowed indefinitely | allowed | Charger can "wake-up" charge indefinitely; controlled charge allowed |
| 30k to 100k Ω | THERM_COLD | cold | allowed for initial time-out period | allowed | Charger can "wake-up" charge for time-out period only. |
| Above 100k Ω | THERM_OR, THERM_COLD | over-range | not allowed | not allowed | Can be used as battery detect; charger does not supply current. |

Smart Charger Safety Issues (cont'd.)

- Level 2 “controlled” charging safety
 - Communication failures
 - Failure to receive the correct voltage and current limit
 - Slow update of the limits
 - Voltage over-stress of battery electronics
 - Improper placement of circuit breakers

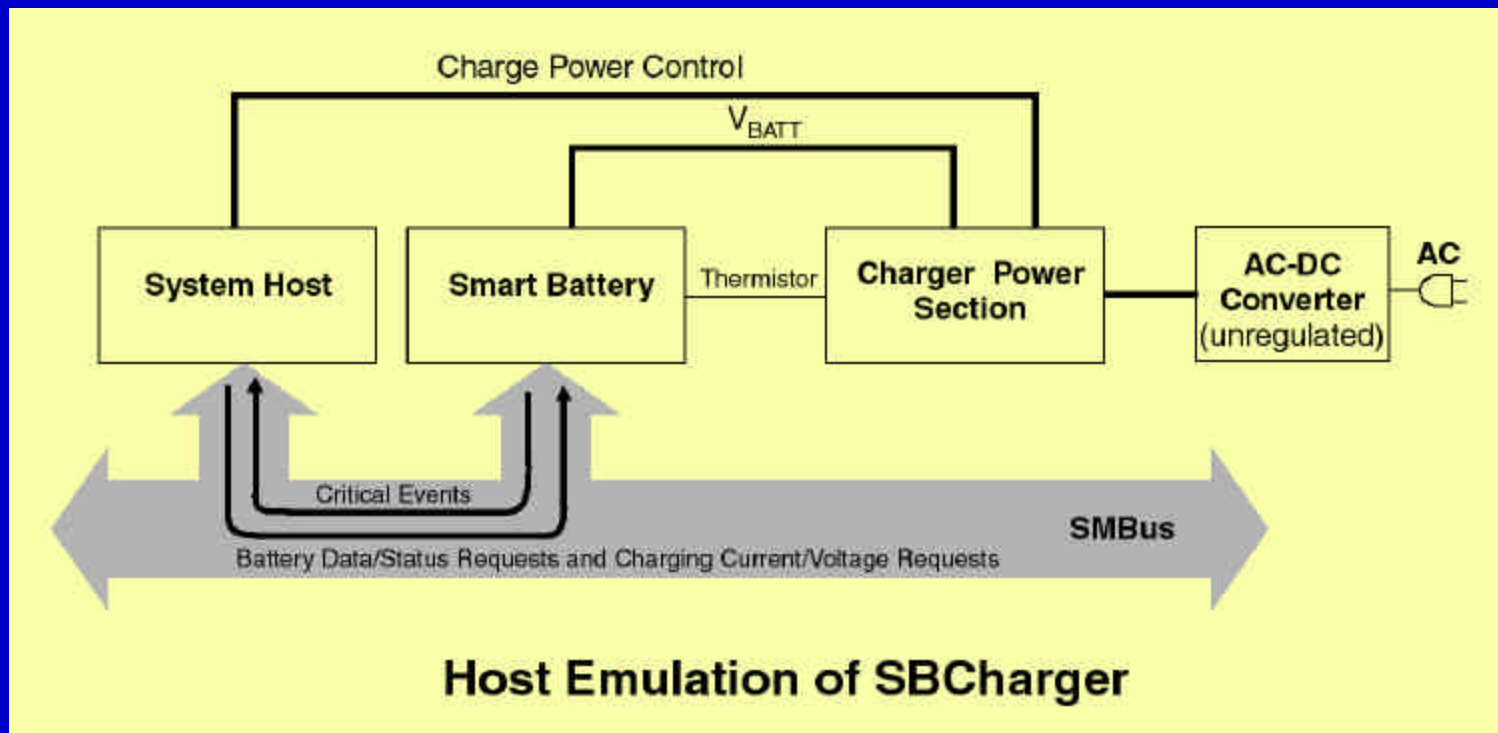
Smart Charger Safety Issues (cont'd.)

- Level 3 “controlled” charging (Host-controlled charging)
 - The charger controller requests data from the battery for voltage and current limits
 - The charger controller requests data from the battery status
 - The charger can implement a special charging algorithm
 - Charge termination may not result in the battery reporting full capacity
 - The battery may issue early charge termination request

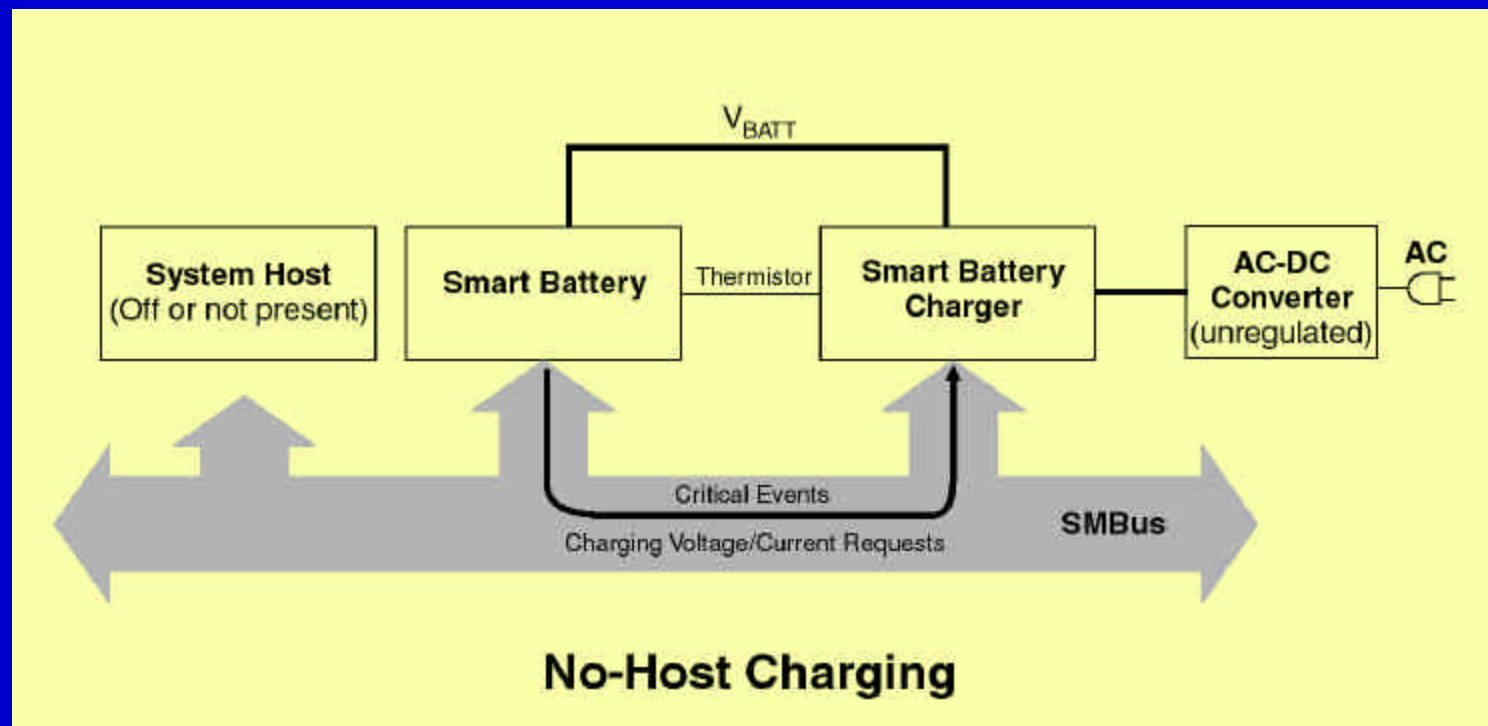
Smart Charger Safety Issues (cont'd.)

- Level 3 “controlled” charging safety
 - Communication failures
 - Most feel that this is better controlled than in the Level 2 case
 - Could result in more bus traffic
 - Voltage over-stress of battery electronics
 - Improper placement of circuit breakers

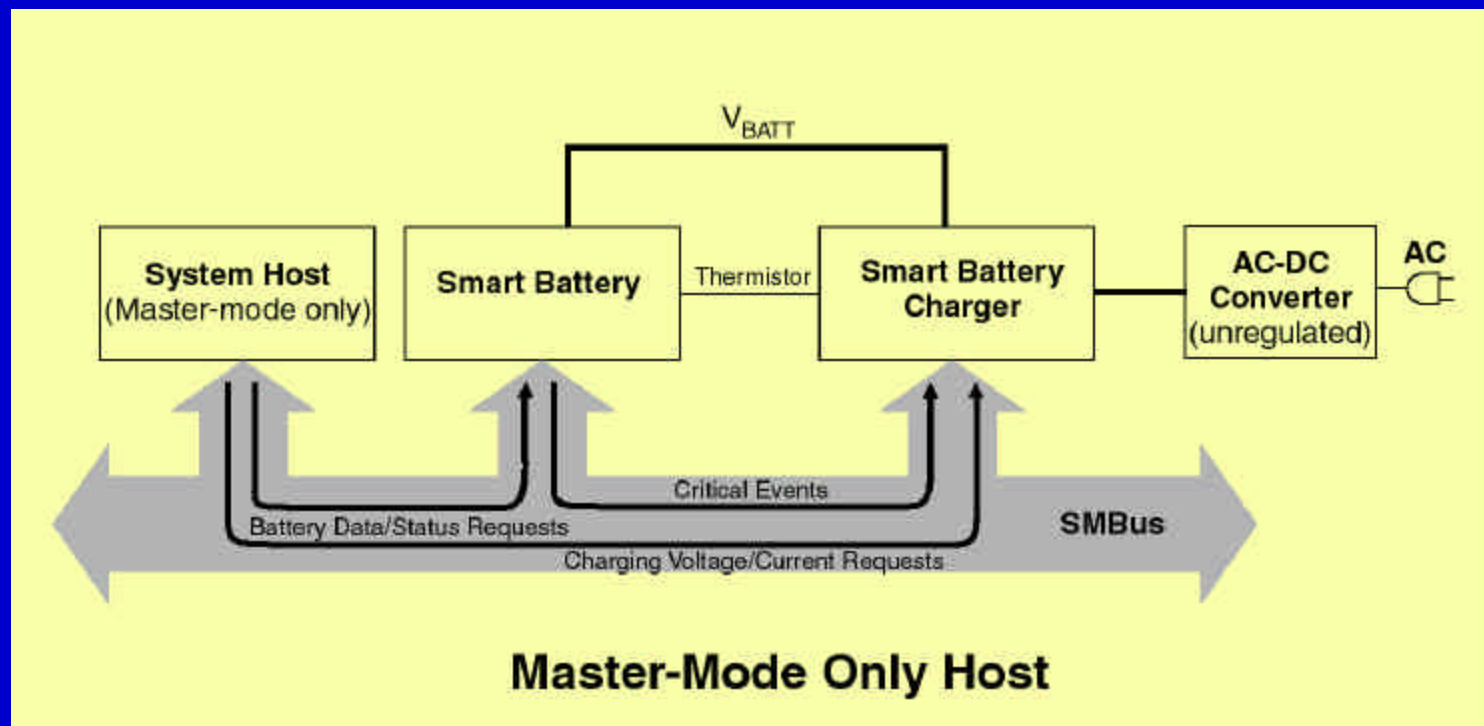
Smart Charger Implementation Topologies



Smart Charger Implementation Topologies



Smart Charger Implementation Topologies



Smart Charger Accuracy and Safety

- Battery and charger closed-loop regulation
 - Battery charging voltage or current limit is adjusted for best conformance to request
 - Adjustment is made based on a safe modification of the voltage or current
- The actual loop timing is not specified
- Charger non-conformance conditions may not be known by the battery

Required Smart Charger Commands

- AlarmWarnings are used to stop charging due to the battery's status
- ChargingCurrent is the charging current limit
- ChargingVoltage is the charging voltage limit

Required Smart Charger Commands (cont'd.)

- ChargerSpecInfo indicates the charger specification ID and command set
- ChargerMode is used by the Host to set the charger operational modes
- ChargerStatus indicates the charger type, thermistor limit, regulation, and power condition

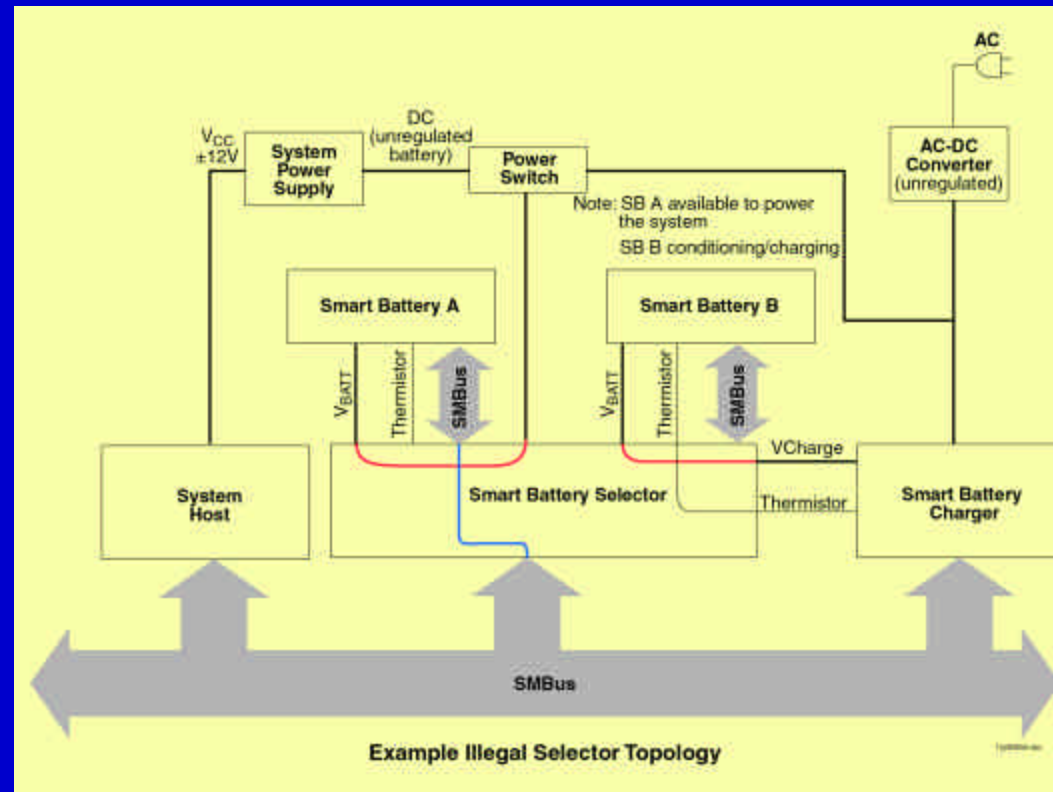
Smart Selector

- Purpose
 - Select the system-to-battery communication path for multiple-battery systems
 - Select the power source for the system
 - Select the battery to be charged
 - Inform the system when the power state changes

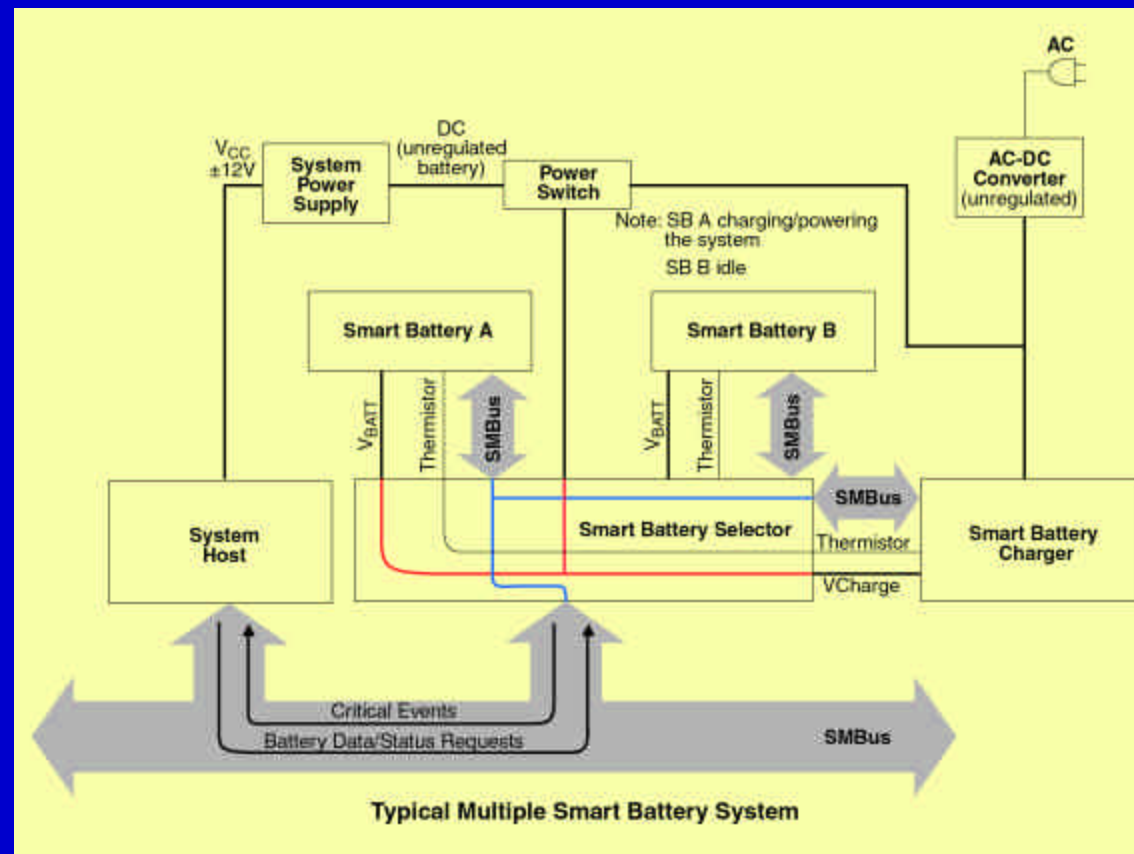
Smart Selector (cont'd.)

- Requirements
 - Prevent unsafe conditions
 - Discharging one battery into another
 - Controls the communication connection from the battery and the charger
 - Switching to another power source when one source is removed
 - Allow the host to communicate with any battery in the system
 - Notify the system when the power source has changed

Illegal Smart Selector Topology



Typical Smart Selector Topology



Smart Selector Commands

| Function | Code | Access | Data |
|----------------------------|---------------------|--------|-------------|
| reserved | 0x00 | | |
| SelectorState | 0x01 | r/w | packed word |
| (Optional) SelectorPresets | 0x02 | r/w | packed word |
| SelectorInfo | 0x04 | r only | packed word |
| reserved | 0x03, 0x05 -0x2e | | |
| OptionalMfgFunction5 | 0x2f | r/w | data |
| reserved | 0x30 -0x3b | | |
| OptionalMfgFunction4 | 0x3c | r/w | word |
| OptionalMfgFunction3 | 0x3d | r/w | word |
| OptionalMfgFunction2 | 0x3e | r/w | word |
| OptionalMfgFunction1 | 0x3f | r/w | word |

Smart Selector Safety Issues

- Allowing one battery to discharge into another
- Allowing a charger to charge a battery that can not communicate to the Host or charger
- Not switching power sources in a timely manner
- Not switching the battery thermistor properly

SBS & Safety Conclusion

- SBS provides for safe battery operation
- SBS allows for additional non-SBS safety measures
- SBS integrates the battery, charger, and power management communication to provide safety system operation