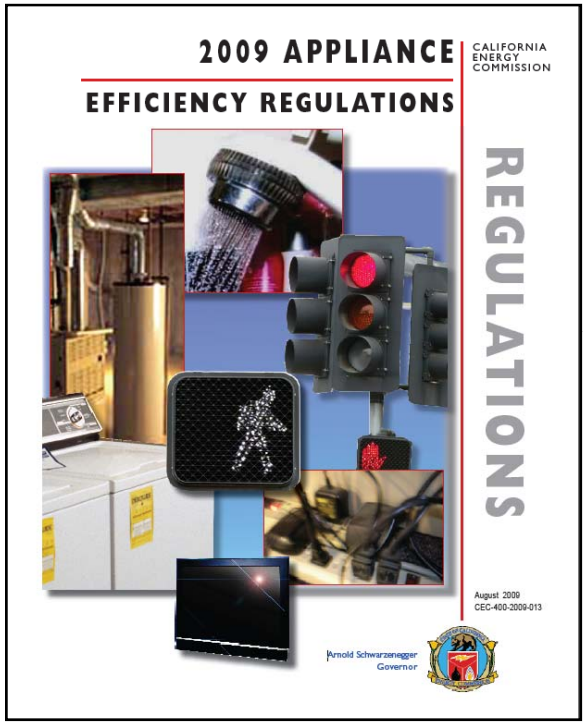

Title 20 California Efficiency Standards for Battery Charger Systems: Current Issues

May 19, 2011
California Energy Commission, Efficiency Committee Workshop

Docket No. 09-AAER-2; RE: 2010 Rulemaking proceedings
Phase II on Appliance Efficiency Regulations

Presentation by:
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Outline

- Concept design questions
- Test procedure approach and changes
- Recommend increase in stringency for maintenance mode and power factor
- Recommended compliance timing
- Large chargers changes to express terms
- Energy savings opportunity

Concept design

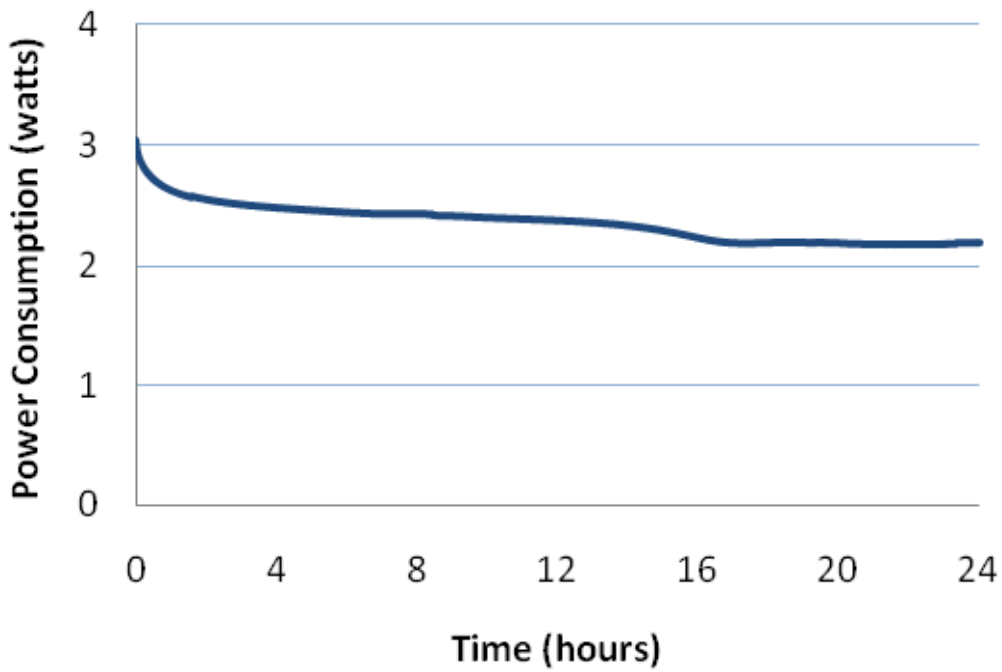
Two detailed studies to improve energy efficiency

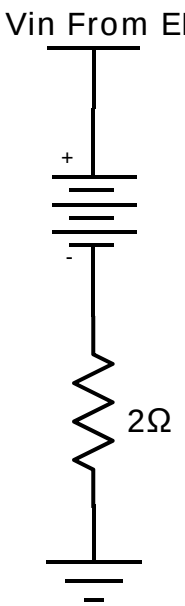
DIY 15 Wh NiCd power tool charger
Cost: $60 from Home Depot (Feb 2011)

1.5 Wh NiMH beard trimmer
Cost: $18 from Target (Jan 2011)

Products selected based on manufacturers' comments concerning cost effectiveness

DIY power tool efficiency improvements needed: charge termination/maintenance

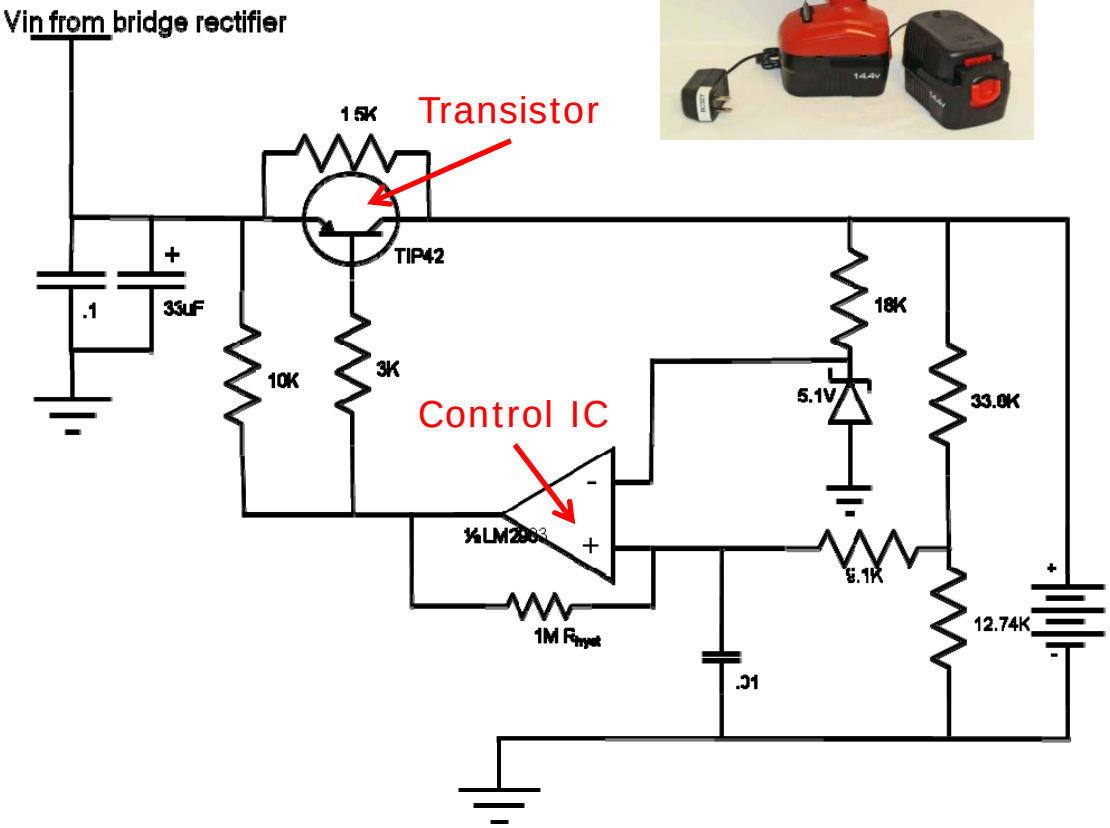




Mode	24-hour efficiency	Maintenance	No-battery
Proposed Title 20	45%	0.5 W	0.3 W
As shipped	35%	2.2 W	0.25 W

Simple charge control possible to improve charge and maintenance mode efficiency

- Replaced resistor as current regulator with a transistor controlled by a voltage comparator: reduced maintenance power
- Circuit can be converted to hysteresis charger by removing trickle resistor bypassing the transistor



Title 20 proposed levels cost-effectively achieved with improved charge control and more efficient level "V" EPS

Mode	24-hour efficiency	Maintenance	No-battery
Proposed Title 20	45%	0.5 W	0.3 W
As shipped	35%	2.2 W	0.25 W
Modified: charge term. +V EPS	54%	0.40 W	0.30 W

- Incremental BOM cost for redesign (OEM quantity): ~$0.55
- Incremental cost for level V EPS: $0.10 (may go down as copper prices increase)
- Total with markup is $1.20 (1.81x in DOE method)
- Payback period: 0.5 years, 14 kWh/year annual savings

Concept design of power tool adds consumer-valued utility

- Concept replicated all the features of the product as shipped, including charge LED
- Charge control enables slightly faster charge time than product as-shipped
- More expensive and precise components required are common to many consumer high-tech products, possible for appliance battery chargers as well
- Tests of concept designs suggest reliable return of total battery capacity
  - If trickle is insufficient to maintain voltage (e.g. high temp), hysteresis charging initiates to maintain battery

Incremental BOM costs of concept designs are accurate

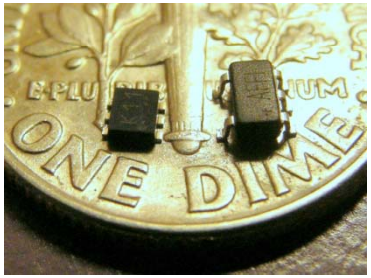
- BOM reported all costs needed for improvements, including:
  - high precision resistor
  - required circuit board material (FR4)—did not remove the cost of the original board material
  - EPS (source: DOE's preliminary analysis)
- Power factor correction not required for this product in past or current proposal
- Markups compounded, like DOE's own analysis
  - E.g. power tool (Class 4): incremental: BOM to MSP 1.5x, MSP to retail: 1.13x, tax 1.07x =1.81x

Concept design can be adjusted to accommodate market needs

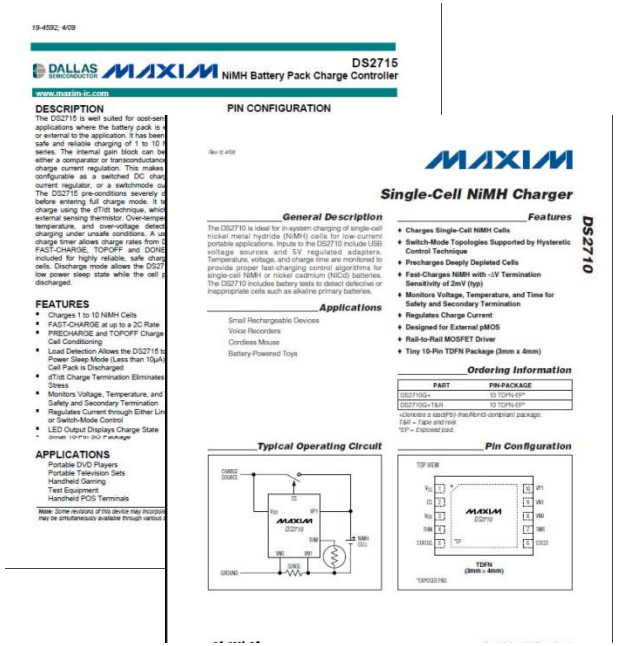
- If design requires operation in variable temperature can easily adjust the cutoff voltage based on temperature
  - thermal compensation network (thermistor and a few other resistors) BOM ~$0.05
  - Well within range of cost-effectiveness: total consumer cost: $1.30 and payback 0.6 yr
- Power tool cost to benefit ratio demonstrated (1:10) allows for these types of additional costs
  - Total energy savings of 14 kWh/year based on CEC published duty cycle assumptions Feb 2011: 4% charge time, 48% maintenance, 15% no battery, 32% unplugged
  - Cost is net total costs and benefit is net total savings

LiIon products already use Si control
“Off the shelf” Si solutions available for efficient battery management for Nickel

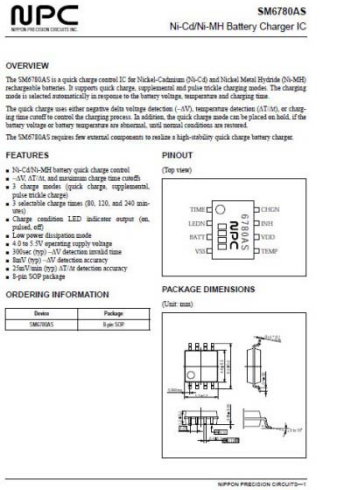
Comparators & comparators with references



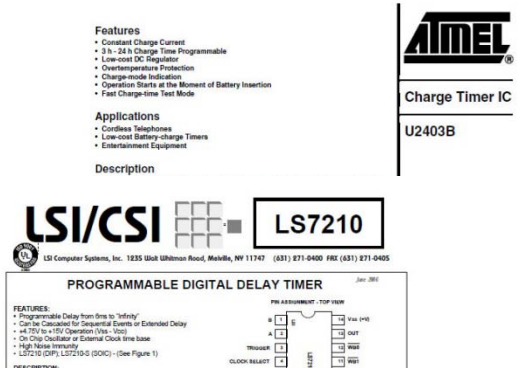
dT/dt with voltage comp. & timer



Neg.ΔV with *dT/dt* & timer

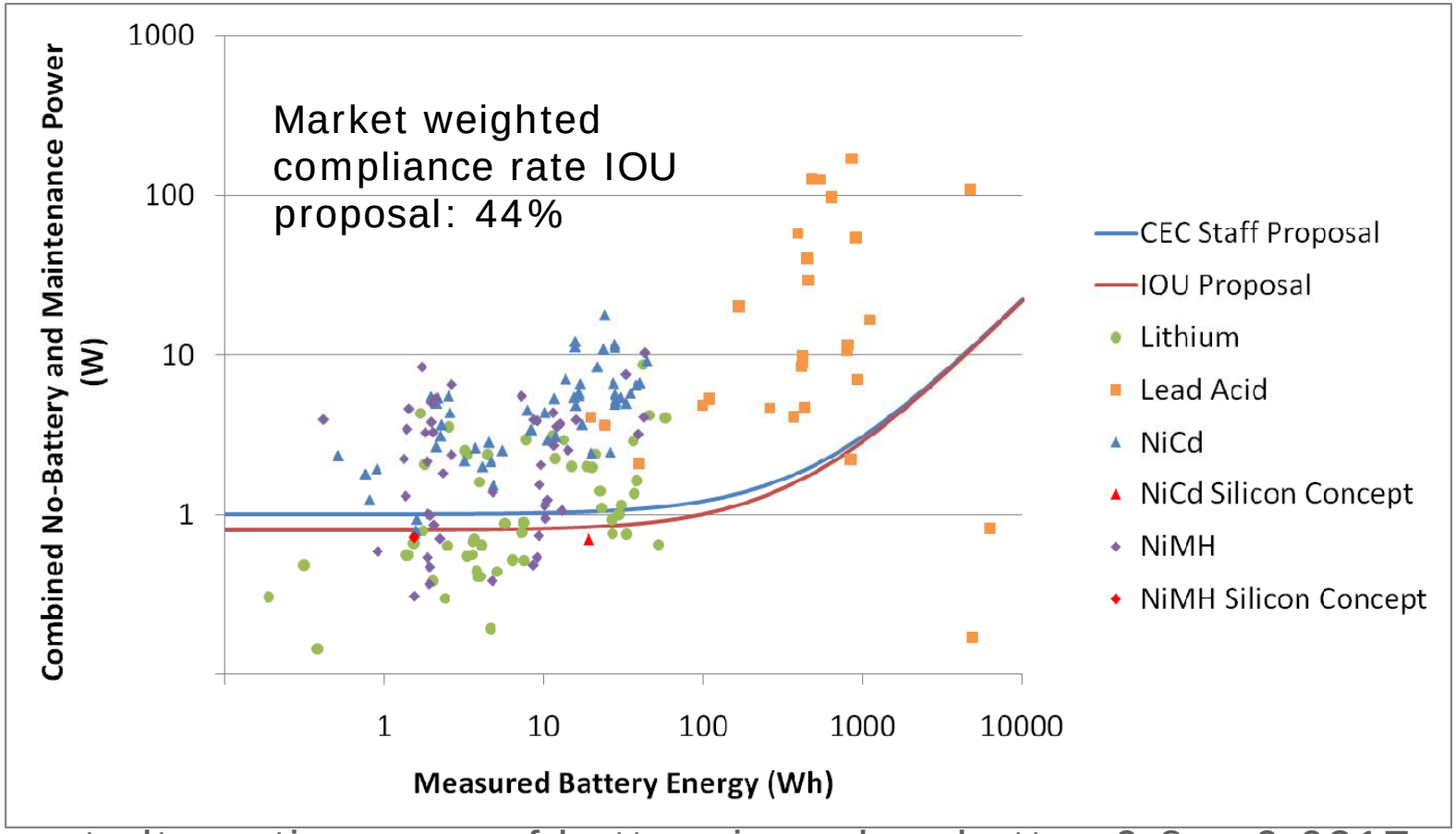


Timers



Battery maintenance and power factor

CEC low power metric does not capture all cost-effective savings



Suggest alternative: sum of batt main and no batt < $0.8 + 0.021E_b$
Original proposal: battery maintenance 0.5 W, no battery 0.3 W
Additional savings of 20 to 50 GWh per year, equivalent to 3000 to 8000 CA households

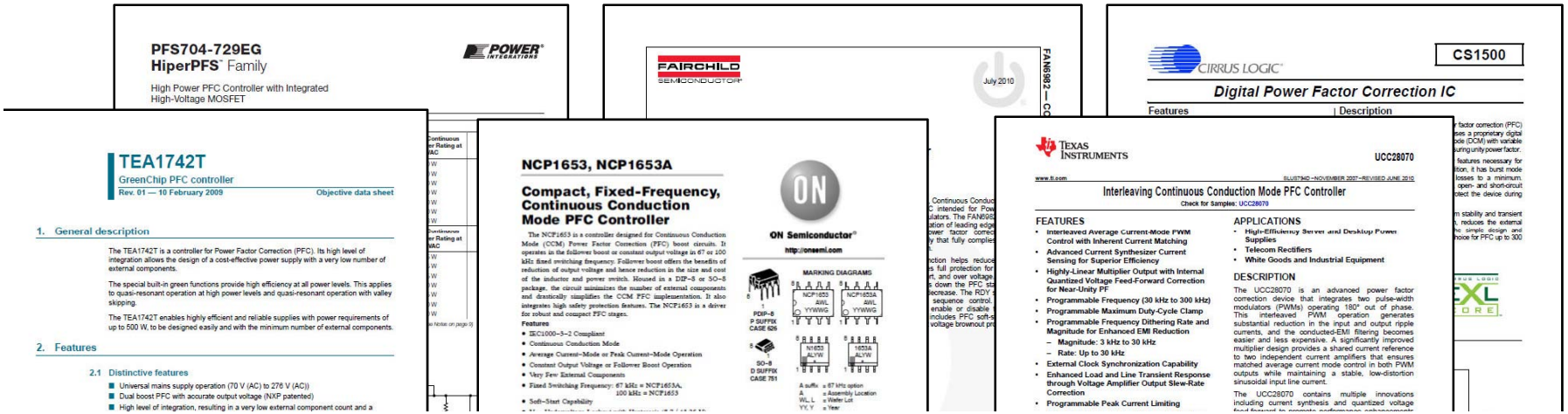
Active power factor correction to reach 0.9 power factor cost effective for higher currents

Application	Incremental BOM cost	Wiring energy savings (kWh/yr)	Payback (yr)
High power laptop	$0.90	13	1.0
Commercial fast charging power tool	$0.90	2.5	5
Auto/marine	$0.90	8	1.6
Personal electric vehicle	$0.90	53	0.2

>60 W input power
Markup of 2x

Power factor requirements for products >100 W should be retained

- Savings is significant: 20 to 60 GWh per year of savings, equivalent to 3000 to 9000 CA homes
- Si power correction solutions widely available from many vendors



Test Procedure

All information to perform test should be possible with readily-available manufacturers' instructions, the product and the test procedure

- Any independent laboratory or U.S. government policy agency (EPA, DOE, etc.) must be able to determine efficiency level of products in repeatable and reliable fashion
- Final CEC test procedure enables this by specifying: battery selection, test set up, etc.
- Specifies all user-selectable functions be turned off, product only operating as a battery charger
- Other functions are in "standby" mode with enough power to recognize when the user wants to turn on the function

Energy Efficiency Battery Charger System Test Procedure

Version 2.2, November 12, 2008

Adopted by the California Energy Commission on December 3, 2008 with typographical error corrections.

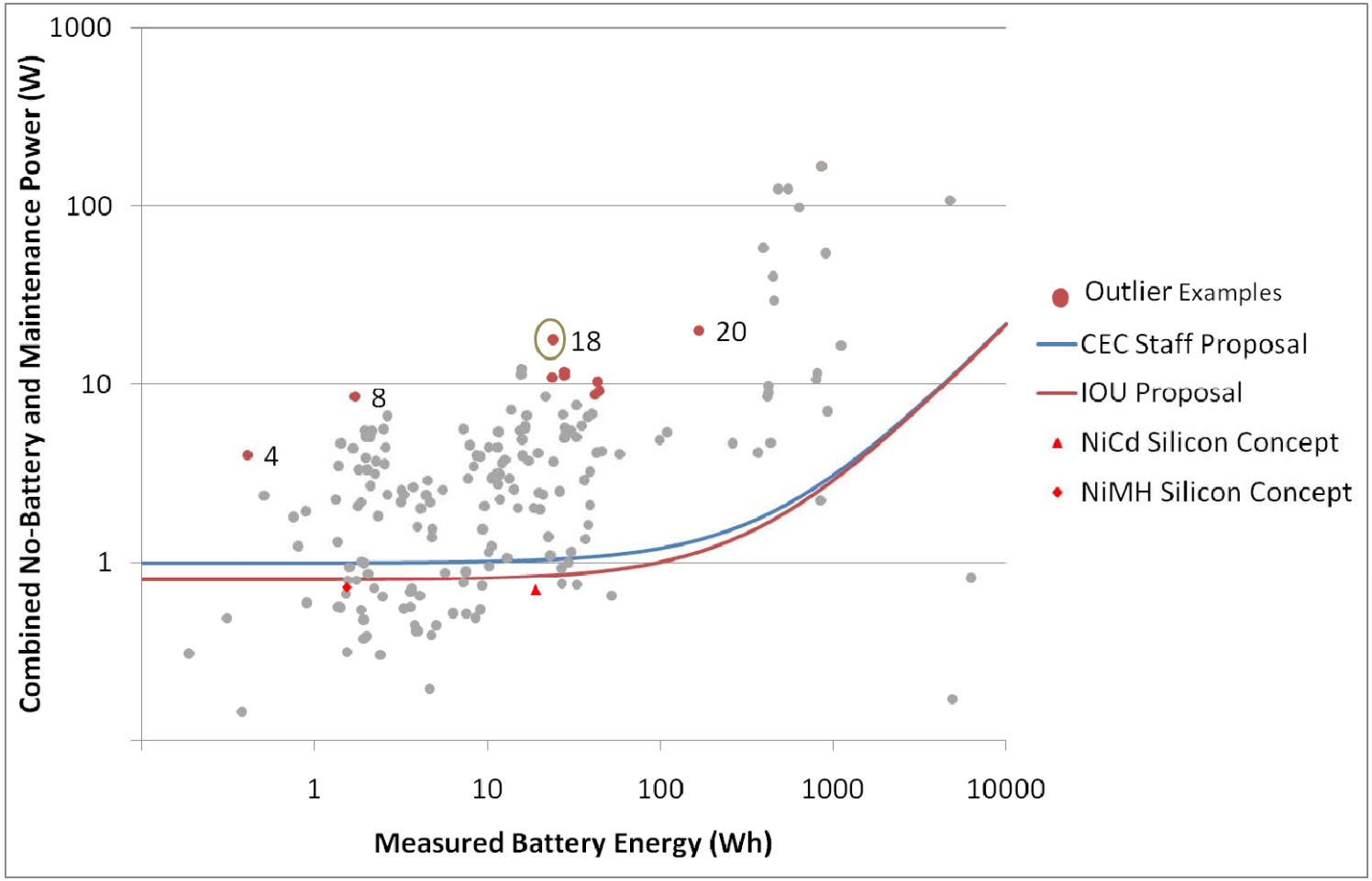
Suzanne Foster Porter and Paul Bendt, Ph.D., Ecos Consulting
Haresh Kamath and Tom Geist, EPRI Solutions
Jordan Smith, Loïc Gaillac, and José Salazar, SCE

Development funded by: Pacific Gas and Electric,
California Energy Commission-Public Interest Energy Research (PIER) Program,
and Southern California Edison

No physical changes should be made to the product under test

- Cutting traces, wires, etc. for non-battery charger function not recommended
- Test procedure should represent normal use by the consumer, cutting traces is not a normal consumer activity
- Standard accommodates fixed losses in battery charger in both metrics, latest version even more flexibility
- No changes should be made to test set up in the test procedure

When the product function is battery charging, all other functions should be in standby



Possible lost energy savings:

300 GWh per year

Equivalent electricity use of 45,000 CA homes

Switches are off, still uses 9 watts in low power modes

- Power tool w/ entertainment center
- Tested with 24 Wh battery capacity
- 9 W maintenance power
- 9 W no battery power
- Energy use of product would not change dramatically even under standard if test procedure is changed
- Only one of a dozen examples of poor power scaling in the PG&E dataset

Power scaling solutions for indication and fans available

- Cooling fans and indicators inherently part of charging system, not extra functions
- Not significant energy use to indicate status of charge to consumer with indicator lamps and audio indicators
  - LEDs for bright ambient conditions are 10 to 50 mW per LED
  - Could have 10s of LEDs under the current CEC proposal
  - Audio not continuous through maintenance mode and charge mode
  - Short indication for battery status conditions
- Cooling fans
  - Part of charging process
  - Can be controlled with timer or thermostat

2008 test procedure accounts for other functionality, connections

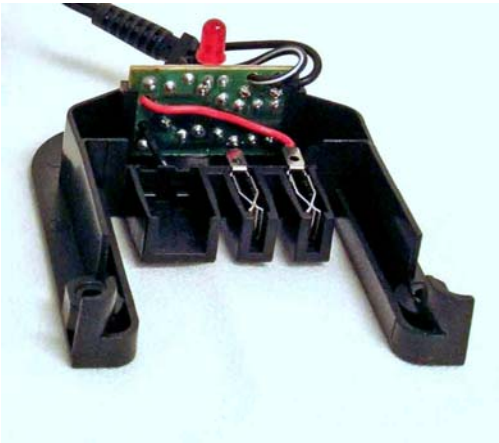
- Turn off other functions where possible
  - Manufacturers can include hard-off switches for other functions
  - Implement standby power levels for those functions without hard-off switches
- Leave other cables disconnected
  - Other connections usually don’t affect the battery charger function or its energy use
  - Lab does not need to provide other connections and signals
  - Other connections might cause the device to consume more power

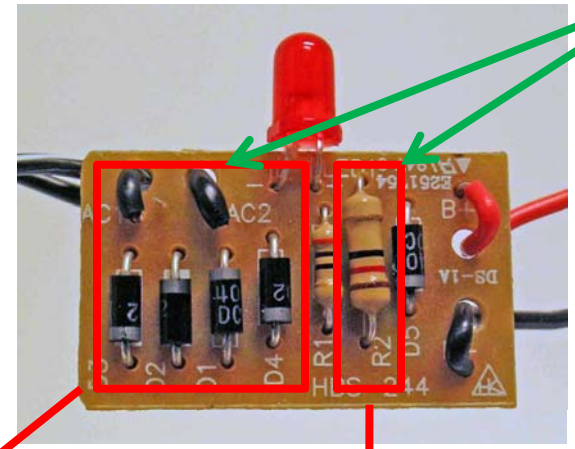
Timing

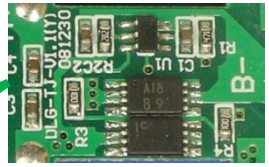
Proposal provides flexibility to achieve 12 month compliance timeframe

- Alternative battery maintenance and no battery proposal gives more flexibility to trade fixed losses between modes
- Reduced scope for power factor requirement simplifies design and reduces need to manage fixed losses
- Many improvements (e.g. power supply efficiency, and charge control) improve both metrics, making compliance easier to achieve

Plenty of room for Silicon charge control on existing circuit boards







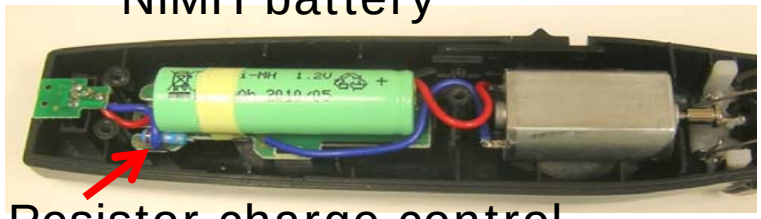
Surface mount Si charge control occupies vacated space

Rectifiers move into new EPS

Charge resistor no longer needed

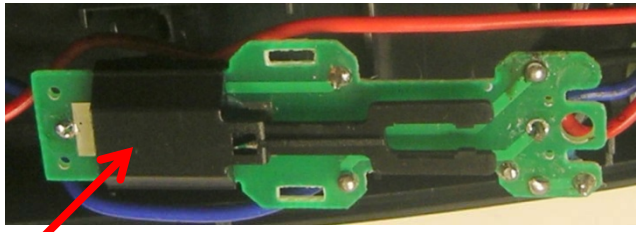
Wider adoption of Li-Ion has demonstrated that Si charge control can be implemented with little or no packaging or shipping impact

NiMH battery



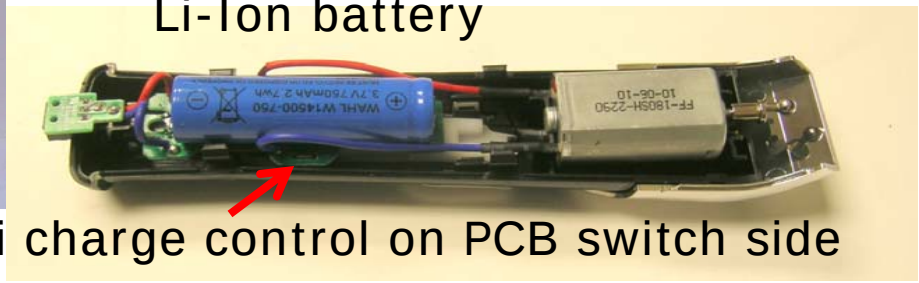
Resistor charge control

PCBs are same size & mount



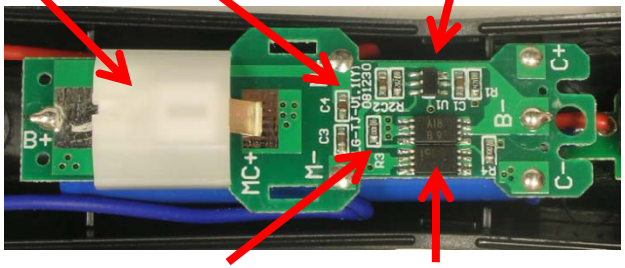
Switch assembly

Li-Ion battery

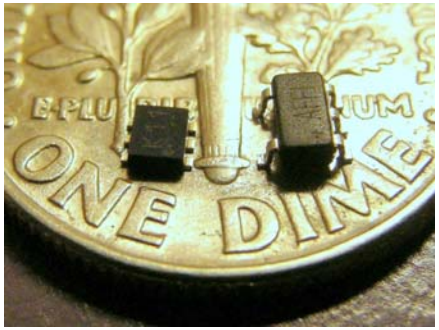


Si charge control on PCB switch side

Capacitors(4) Control IC



Resistors(4) Transistors



•These small “off-the-shelf” packages allow Si based charge control to fit in existing PCB space

Few additional costs associated with redesign in one year

- Consumer products are regularly redesigned to encourage consumer upgrade to new models and to distinguish product in the market
- Circuit design and board design can be absorbed into regular OEM redesign schedules
- Changes to product molding not required, components required are small and fit on existing circuit board space
- Markup on extra components applied in the analysis (2x) easily covers these costs
- Full safety testing unlikely required with these changes, turnaround likely 4 weeks
  - Using new EPS—no recertification required unless EPS interacts with battery charge circuits
  - Using new battery charger circuitry—retest for safety if outside standard ranges specified by battery manufacturer: estimate $2,000 to $3,000

Only mission critical non-consumer chargers need 2 year compliance

- Mission critical chargers carried by public emergency personnel
- Can meet the proposed standard, even with spark generation protection, high brightness LEDs, fans, other
- Because of unique safety role, 24 month compliance timeframe justified
- All other non-consumer products should meet 12 month timeframe
- Energy savings difference worth 110 GWh, or energy use of 20,000 CA homes for one year

Large Chargers

Changes to large charger express terms

- Suggest different approach to large battery charger selection
  - Test should be focused on charge algorithm, not battery chemistry type
- Recommend that Tier 1 be retained (1 year implementation)
  - High efficiency chargers available now can charge all batteries
  - 15 GWh life cycle savings for one year of sales, equivalent to 2000 CA homes for one year

Battery charger standards savings

Small BCS energy savings	55 to 65% of current energy use; 2,300 GWh life cycle savings from first year sales
Large BCS energy savings	8% of current energy use; 300 GWh per year (Tier 2) after stock turnover (if current stock)
All BCS energy savings	35% of current energy use
Rosenfeld	0.9 after stock turnover if current stock
Equivalent energy savings	350,000 households

- Per product incremental cost $1.80, lifetime unit energy savings $14
- Cost: benefit = 1:8
- Net present value of consumer energy savings from first year of sales is $250 M, orders of magnitude greater than the cost of regulation