CHARGETEK

409 Calle San Pablo, Unit 104
Camarillo, CA 93012
(866) 482-7930
www.chargetek.com

POTENTIAL DIFFERENCE Inc.

7582 Las Vegas Blvd. South #219
Las Vegas, NV 89123
(702) 576-1717
www.potentialdifference.com

True rapid charging technology

Rapid charging: breakthrough technology

There have been many rapid charging claims and products in recent years. Chargetek has developed a true rapid charging technology. It can safely provide an 80% charge in 20 minutes. Based on proven patents, chemical analysis, and confirmed with extensive testing, there is no doubt that our company's technology outperforms anything available on the market today. This technology is currently available through licensing or finished product.

- Patented and proven rapid charging algorithm
- Applicable for batteries ranging from lithium ion 18650 cell to 20,000Ahr batteries
- Applicable for lead based chemistries such as AGM, SLA and maintenance free
- Applicable for lithium cobalt oxide and lithium iron phosphate
- Does not overheat or overvoltage the battery
- Closed loop feedback of temperature, voltage and charge current ensures safe and optimal charging
- Proprietary software can be customized per application

Rapid charging features

We can safely provide a 20% – 80% charge in 20 minutes

- ***Applicable for batteries ranging from lithium ion 18650 cell to over 20,000Ahr batteries***
- Applicable for lead based chemistries such as flooded, AGM, SLA and maintenance free
- Applicable for lithium cobalt oxide and lithium iron phosphate
- Does not overheat or overvoltage the battery
- Closed loop feedback of temperature, voltage and charge current ensures optimal charging
- Proprietary software can be customized per application
- Extensive engineering support to realize the rapid charger for your specific application

Rapid charging applications

Solar and wind power

- Able to use maximum power when available
- Power scalable depending upon weather conditions

Forklifts

- Capable of charging two trucks simultaneously at full power
- Reduces cost of extra trucks
- Minimizes downtime of personnel and equipment

Portable equipment

- Provides high availability
- Rapid charger can be embedded on an OEM basis

First responders

- Provides peak conditions of batteries at all times
- Able to charge quickly during emergencies

Electric vehicles

- Provides for significant opportunity charge
- Applicable to a wide range of battery pack voltages
- Rapid charger can be embedded on an OEM basis

Material handling

- Provides high availability
- Minimizes downtime of personnel and equipment
- Rapid charger can be embedded on an OEM basis

Concurrent rapid charging of a dual battery bank system

Great cost effective solution for material handling and alternative energy applications

- Our patented and proven algorithm can rapid charge two large battery banks from one charger
- Each battery bank is independently regulated
- Faster charging results in lower required battery pack capacity
- Charge and discharge cycles occur alternately
- Drastically reduces charger cost and space
- Modular design provides redundancy and fault tolerance

How concurrent charging works

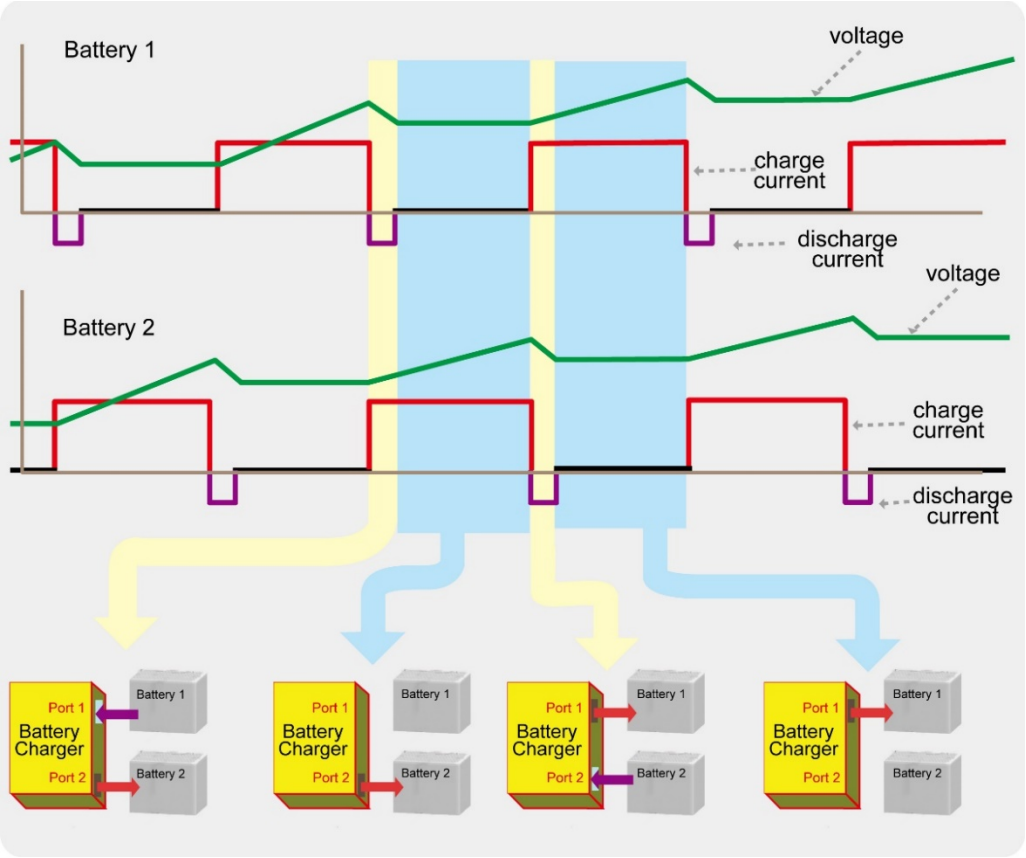
Overview of operation

The battery charger has two ports, one for each battery pack. Battery pack 1 and battery pack 2 are alternately charged and discharged. In the figure below, the battery voltage curve is depicted in green, the battery charging current is depicted in red and the battery discharge current is depicted in purple.

A positive voltage slope (voltage increase) is generated during charge. A negative slope (voltage decrease) is generated during discharge. The flat area is the rest period of the charging cycle. The positive charging current amplitude can be three to four times the magnitude of a conventional charger due to our patented algorithm.

The industry standard charging current is based upon the amp hour (Ahr) rating of the battery and is denoted by C. For example, if each battery pack is 500Ahr, then the standard charge rate would be in the range of C/3 - C/5 resulting in a charging current range of 100 - 170 amps. There would be variations depending upon the characteristics of a particular battery. For this particular application, the charge current would be set to 2C (1000A) with a 50% duty cycle resulting in a charge rate of C or 500 amps. The discharge current would subtract from this slightly. The resulting charge time would be approximately 1.1 hours. This charge time is two to three times faster than what would be attainable using a conventional charger. With a conventional charger, the charge current would be limited to a maximum of C/3 or 170 amps.

The cost savings would be significant since there is only one charger required for two battery packs. In addition, at least twice as many battery packs could be charged in the same time. In summary, our charger has four times the charge capacity of a conventional charger.



Motorola X free fall TV commercial

Moto X: Charge 8 hours of battery life in 15 minutes

Our technique in comparison

- 8 hours of battery life in 6 minutes
- Over 21 hours of battery life in 15 minutes

Calculations

- Rated battery capacity is 48 hours. 8 hours = 17% of rated capacity (8h/48h)
- Our algorithm will charge from 20% to 80% (60%) in 20 minutes
- In 15 minutes, provides a 45% charge (15/20 = 75%, 75% of 60% = 45%)
- 17% / 45% x 15 minutes = 5.67 minutes = ~ 6 minutes
- 45% x 48 hours = 21.6 hours

Obstacles to rapid charging

Batteries have three intrinsic limitations during a charge cycle.

- Maximum battery voltage
- Maximum battery temperature
- Maximum allowable charging current

Exceeding any parameter can cause undercharging, overcharging, overheating or physical degradation, resulting in severely reduced battery life. The challenge is to maintain a significant charge acceptance while charging at an elevated current.

The consequence of conventional high current charging results in concentration polarization and electrochemical polarization

- Electrochemical polarization is an imbalance of ions and a difference in electrochemical reaction speed between the two battery electrodes. This reduces the charge acceptance and causes excessive battery temperature
- Concentration polarization, where the battery solution (electrolyte) has a higher concentration at one electrode than the other. That causes excessive voltage that damages the battery.

Rapid charging a Panasonic 18650

To replenish 60% capacity for a 3000mAhr capacity cell in 20 minutes, an average current 5.4 amps is required:

Average current = 60% x amp hour capacity x (60min /20min) = 5.4 amps

The average manufacturer recommended charging current is .883 amps.

How to provide the current required while maintaining battery safety and life? Our algorithm circumvents the battery's physical limitations:

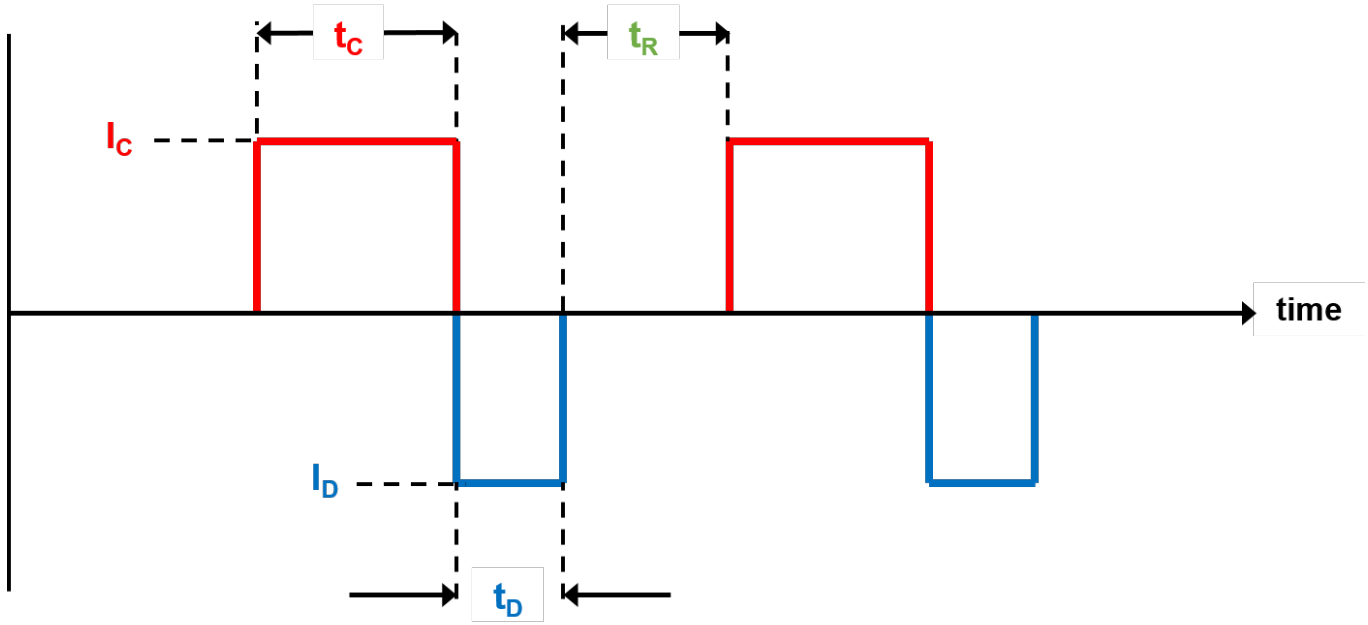
- Reduces electrochemical polarization by providing regular rest periods to allow the ions to disperse evenly between the two electrodes
- Concentration polarization is eliminated by applying a comparatively short duration reverse pulse, either preceding or following the positive charge pulse
- Temperature, voltage, and charge acceptance are continually monitored, and from that feedback, the parameters of the charging algorithm adjust continually

Our algorithm has successfully made true rapid charging possible!

Rapid charging algorithm

By reducing heat generating charge acceptance problems and electrochemical polarization, we are able to recharge at exceptionally high currents.

The graphic below depicts the critical waveform parameters.



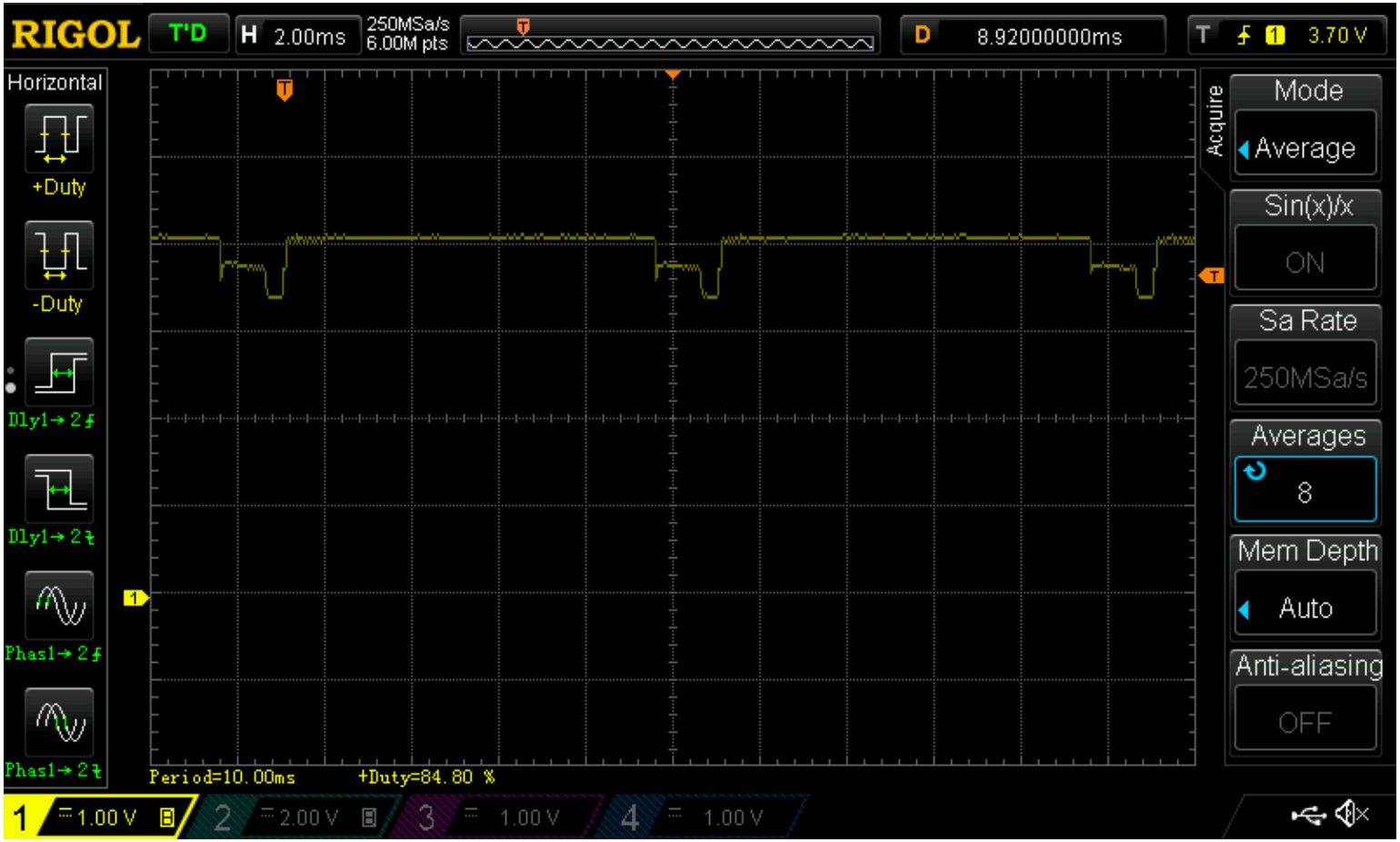
Rapid charging algorithm (cont'd)

Our rapid charge technique is comprised of three fundamental components:

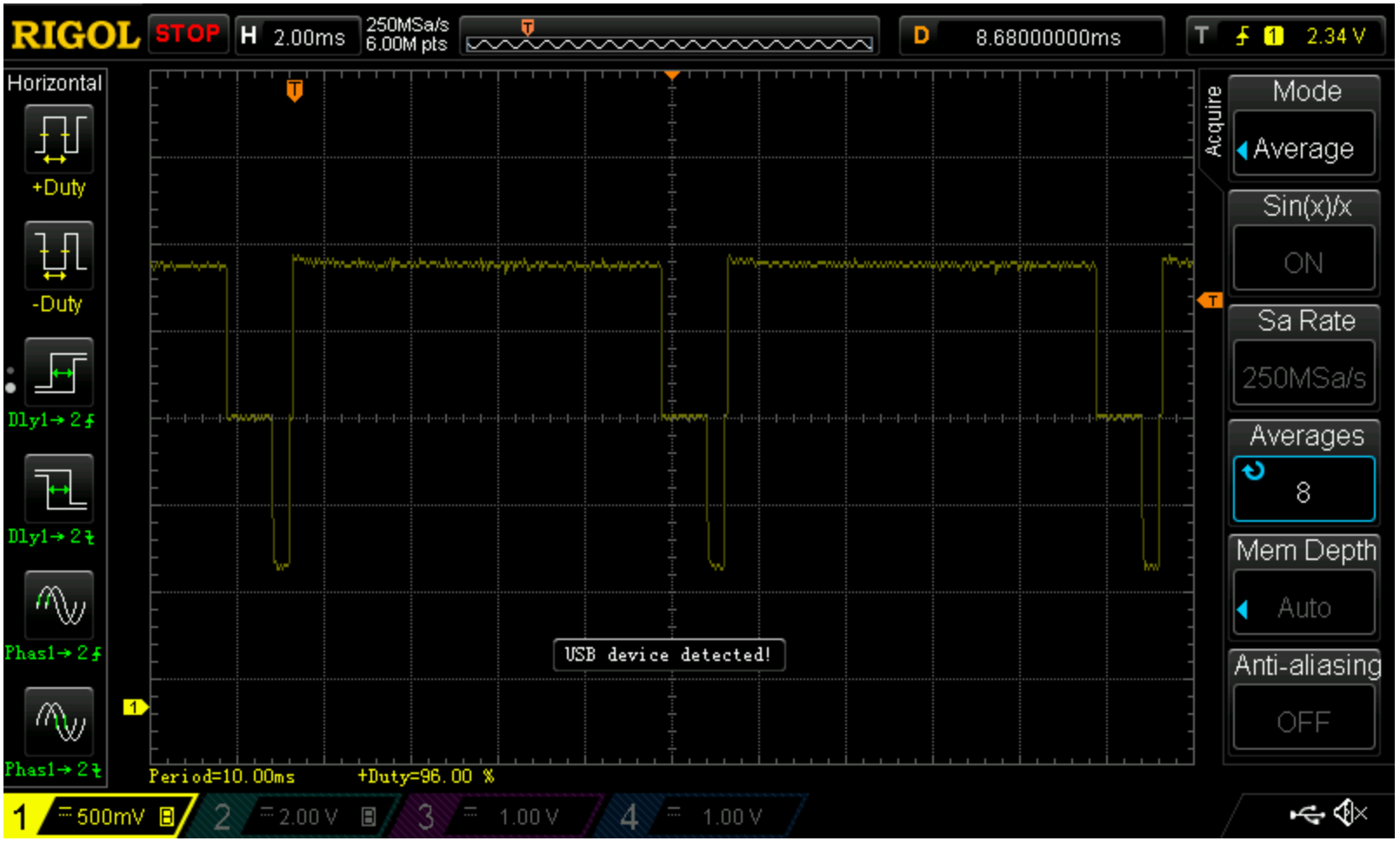
- **Charge current pulse:** The amplitude (I_C) and duration (t_C) is depicted in red. A charge current of two to three times the amp hour rating of the battery is typically employed
- **Discharge current pulse:** The amplitude (I_D) and duration (t_D) is depicted in blue. The magnitude of this current is equal or greater to the magnitude of the charge current. The time duration is a fraction of the charging current
- **Rest time:** The battery current is zero (t_R)

During the entire charging process, battery temperature, rate of temperature change, battery voltage and current are continually monitored and modulated by the proprietary PDI/Chargetek software. The parameters of the algorithm are adjusted in real time during the charge.

Battery voltage



Rapid charge current



Vertical resolution = 4.5A/div

Empirical data

Data was taken for over thirty batteries from five distributors. This data summary is for three batteries charged with different charging parameters. We are in the process of testing fifty cells with various charging parameters to determine the optimal charging configuration for this particular cell. We will also determine if there are any adverse effects on life time or capacity over hundreds of cycles.

	alpha	beta	gamma	duty C	Duty D	Ip C	Ip D	Seq	Tmx	Cap (1.5A)
1	1.5	0.88	30	85	6.0	8	8	D-C	<42 (gauge)	1.87
2	1.5	0.88	30	85	2.8	8	8	D-C	<40 (gauge)	1.84
3	1.5	0.88	30	85	6.0	8	8	D-C	<42 (gauge)	1.83

	alpha	beta	gamma	duty C	Duty D	Ip C	Ip D	Seq	Tmx	Cap (1.5A)
1	1.5	0.88	30	80	3.0	8	8	D-C	<43 (gauge)	1.636
2	1.5	0.88	30	80	3.0	8	8	D-C	<42 (gauge)	1.78
3	1.5	0.88	30	80	3.0	8	8	D-C	<43 (gauge)	1.77

Summary

- Our rapid charging technology is at a minimum very competitive
- The technology is applicable for a broad range of battery chemistries
- We can configure charging systems from watts to kilowatts quickly and economically
- The rapid charge solution is well suited for lead acid based batteries
- We can independently or jointly generate a customized solution per customer specifications
- Contact:

Lou Josephs
www.chargetek.com
Office: (866) 482-7930 x11
Mobile: (805) 444-7792