

# APPLICATION NOTE

## ELECTRONIC LOADS



### Testing EV Chargers and Batteries using Electronic DC Loads



#### Introduction

After several years of rapid developments and investments in new battery and electric traction technologies, the number and types of electric and hybrid vehicles is expanding rapidly. Along with this growing field of vehicle types, infrastructure support of home chargers and rapid public electric chargers is growing fast as well.

All electrified vehicles rely on rechargeable batteries for their electrical energy source. These batteries must be charged at regular interval using either alternating current or direct current charging technology. AC charging is convenient when drawing power from the utility grid.

#### Charging Standards

Prevailing industry charging standards use a variety for voltage and current ratings such as 120V / 12A, 120V / 16A; 220V / 12A, 220V / 16A, 220V / 80A and others de-

pending on region. For fast public charging stations, three phase power is used to shorten charging times significantly. Often, on-board AC chargers are installed in the vehicle so they can be charged from any available AC outlet although charging times using on-board chargers can be quite long as they are often limited in voltage and current capability. However, ready access to standard grid power is an important convenience.

For DC charging, standards are different by region as well. For Taiwan, Japan and the United State, 600V / 200A is typical. For Europe, 850V / 200A is commonly used while mainland China uses a 750V / 250A three phase DC charging standard. DC fast chargers are typically installed in public charging stations and can offer greatly reduced charging times due to their ability to deliver high voltage and high current at the same time for fast charging of DC batteries.



FREQUENCY CONVERSION



AVIATION & DEFENSE



PRODUCTION TEST



ALTERNATIVE ENERGY



R & D



SUPPORT

## Adaptive Power 5VP Series DC Loads

The APS 5VP Series of compact programmable high power DC loads offer 5kW to 60kW per cabinet with test voltages up to 1000Vdc. Models are available at various voltage, power and current combinations to meet specific battery size and voltage/current requirement as shown in the table below. These programmable DC loads were designed to support electric chargers and electric vehicle battery pack development and test and have been deployed by car manufacturers and tier 2 automotive

suppliers all over the world. Of specific importance is the ability of the 5VP programmable loads to operate at full rated power up to 1000Vdc, covering all DC voltage standards used for electric vehicles.

All 5VP Series model DC loads can be equipped with an optional PLC interface for integration into charger and battery production line test systems. The PLC input accepts both digital I/O and analog 0-10V scaled analog signals to control operation of the DC load. Contact Adaptive Power's sales department for further details.

Power / Voltage ->	60 Vdc / Max Current	600 Vdc / Max Current	1000 Vdc / Max Current
5 kW	5VP5-100 / 1000 A	5VP05-16 / 160 A	5VP05-05 / 50 A
10 kW	5VP10-100 / 1000 A	5VP05-32 / 320 A	5VP10-10 / 100 A
15 kW	5VP15-100 / 1000 A	5VP05-48 / 480 A	5VP15-15 / 150 A
20 kW	5VP20-100 / 1000 A	5VP05-64 / 640 A	5VP20-20 / 200 A
25 kW	5VP25-100 / 1000 A	5VP05-80 / 800 A	5VP25-25 / 250 A
30 kW	5VP30-100 / 1000 A	5VP05-96 / 960 A	5VP30-30 / 300 A
35 kW			5VP35-35 / 350 A
40 kW			5VP40-40 / 400 A
50 kW		5VP05-21 / 210 A	5VP50-50 / 500 A
60 kW		5VP05-24 / 240 A	5VP60-60 / 600 A





## Battery Charging Methods

The most common battery charger mode for electric vehicle charging is to use constant current, constant voltage (CC-CV) mode. This means the battery is charged using a constant current level which allows quick charging of the battery while monitoring the battery voltages as it charges up. When the battery voltage reaches its peak voltage, the charger switches over to constant voltage mode preventing the battery voltage from reaching excessive levels. This method is illustrated in Figure 1.

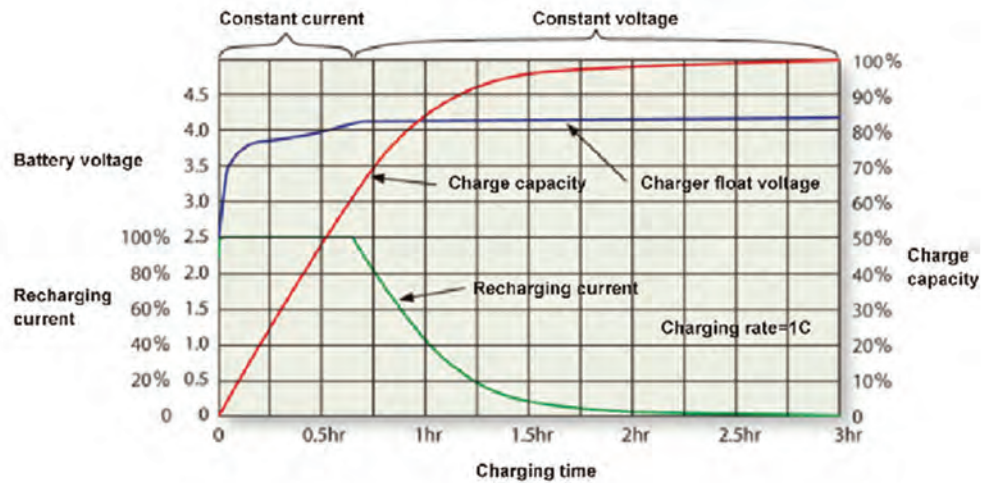


Figure 1: Battery Charging Profiles

## Electric Vehicle Charging Station Test Methods

When charging electric vehicle batteries using an on-board vehicle charger or charging station, the battery represents a load to the charger. During the charging process, the battery voltage will increase slowly. To enhance the speed of the charger to detect the battery voltage, using an electronic load to simulate a battery and its impedance during charger design will enable better and faster test verification.

For battery simulation applications, the most commonly used Load operating mode is Constant Voltage (CV) which simulates the battery voltage or Constant Resistive mode which simulates the battery impedance.

In **Constant Voltage (CV)** mode load mode, the terminal voltage of the electronic load is held at the CV setting voltage value. By adjusting the CV setting value, battery states ranging from fully discharged state to fully charged state can be simulated easily.

In **Constant Resistive (CR)** mode, the terminal voltage of the electronic load is held at the multiple of the charge current and the CR setting value. By changing the CR setting value of the load, various impedance states of the battery can be simulated ranging from fully charged to fully discharged.

As mentioned, Constant Voltage (CV) mode can be used to simulate different state of charge (SoC) conditions of a battery pack during charge and discharge cycles. This include low battery voltage, increasing battery voltage during charging and high voltage state when fully charged. During each stage, the load monitors and displays important parameters such as voltage, power (Watt)

and current. At the end of charge cycle, the load will transition to CC mode to CV mode which will be evident from the load display readouts as well. This approach is much more convenient than using actual batteries to test on-board chargers or charging station operation.

## Load Model Selection

Due to the wide range of electric vehicle charging standards and battery pack sizes used by a wide range of car manufacturers, the power levels and DC voltage and current combinations of the electronic loads used to test these can vary widely. Adaptive Power loads are available in power ranges from as little as 5kW for hybrid vehicle charger testing up to 60 kW for all electric long driving range all-electric vehicle charger testing. Full test verification can be achieved by selecting the correct load model from Adaptive Power wide range of models. If more than 60kW is required, two or more electronic loads can be paralleled to obtain even higher power levels.

All 5VP Series electronic loads are equipped with built-in Over Power Limit (OPL) protection circuits to ensure safe operating when used in parallel mode. The purpose of the OPL feature is to limit the power to the load when the charger output power exceeds the maximum power rating of the load. In that case, the electronic load will automatically limit the input power at or near its maximum power specification and continue to operate at this power level. The OPL function allows two or more electronic loads to be used in parallel for high power applications.

For example, a 20kW charger can be tested using a 25kW

rated electronic load to apply over current, over power conditions to the charger under test. If a 20kW rated electronic load is used instead, no charger over power conditions could be tested.

In case only a 20kW electronic load is available, a 5 kW load model can be added at any time to be used in parallel with the original 20kW load in Constant Voltage

(CV) or Constant Resistive (CR) mode of operation. This is illustrated in Figure 2. This is due to the 5VP load's OPL function which allows CV or CR mode with parallel loads of unequal power ratings. This capability offers great flexibility in deploying multiple loads for a wide range of power requirements.

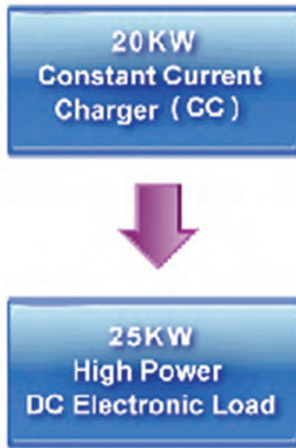


Figure 2: Single Charger connects to a single Load

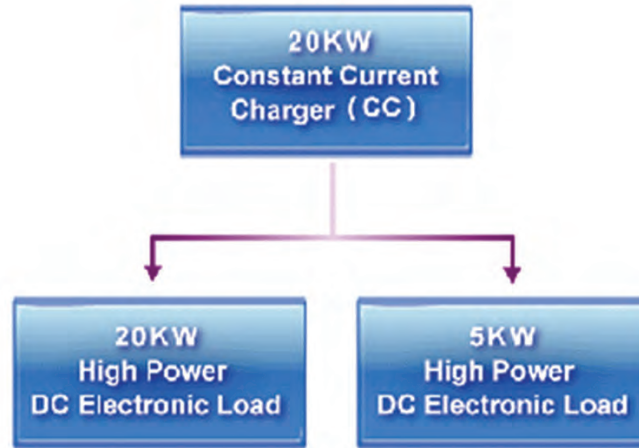


Figure 3: Single Charger connects to two Loads in parallel

## Electric Vehicle Battery Test Methods

Once an electric vehicle's battery is fully charged, it can be driven till almost depleted for maximum driving range. In drive mode, the battery acts as a power source for the electric drive train.

Battery charge and discharge times and associated battery life are important considerations for electric vehicle designs. Another critical design criterion is safe operating area of the battery pack which relates to minimum and maximum charge and discharge voltage levels. For example, a single lithium-ion battery cell's charging voltage cannot exceed 4.2Vdc to prevent overcharging while the discharge voltage cannot drop below 2.5Vdc to avoid excessive discharge. Both conditions can dramatically affect battery life and quickly and permanently dam-

age the internal structure of the battery cell. Therefore, during development and test, careful attention must be paid to charging and discharging voltage levels to avoid permanent battery damage or deterioration.

Adaptive Power Systems 5VP Series DC loads offer the following four operating mode to assist in avoiding conditions during battery discharge testing that could result in permanent battery due to over of under voltage.

1. **CC+CV Mode**
2. **CP+CV Mode**
3. **CC+UVP Mode**
4. **CP+UVP Mode**

Each mode is detailed on next two pages.

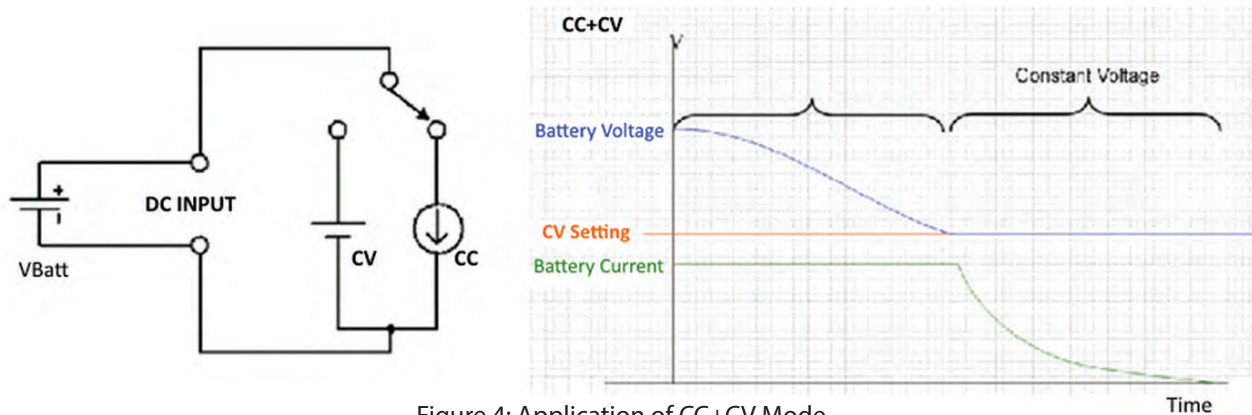


Figure 4: Application of CC+CV Mode

## CC+CV Operation Mode

CC+CV mode is aimed at battery discharge testing. In this mode, discharging of the battery starts in CC mode of operation by setting a current discharge level (CC Set point) and a discharge stop voltage level (CV Set point) which determines full state of charge for the battery under test. When the battery voltage drops to the CV set point level, the electronic load stops discharging so that the battery voltage is maintained at the CV set value. Operation in CC+CV mode is very straightforward as the load automatically switches from CC constant current mode dis-

charge mode to CV constant voltage mode. This prevents the battery from being damaged due to excessive discharging. This mode of operation is illustrated in Figure 4.

### Operation Procedure

- Load input terminals are connected to the DUT
- Change to CC mode and set CC current setting.
- Press Limit key to set the CV voltage and the display will show "Add.CV".
- Press START key to start up the CC+CV test, and press "STOP" key to stop CC+CV Test.

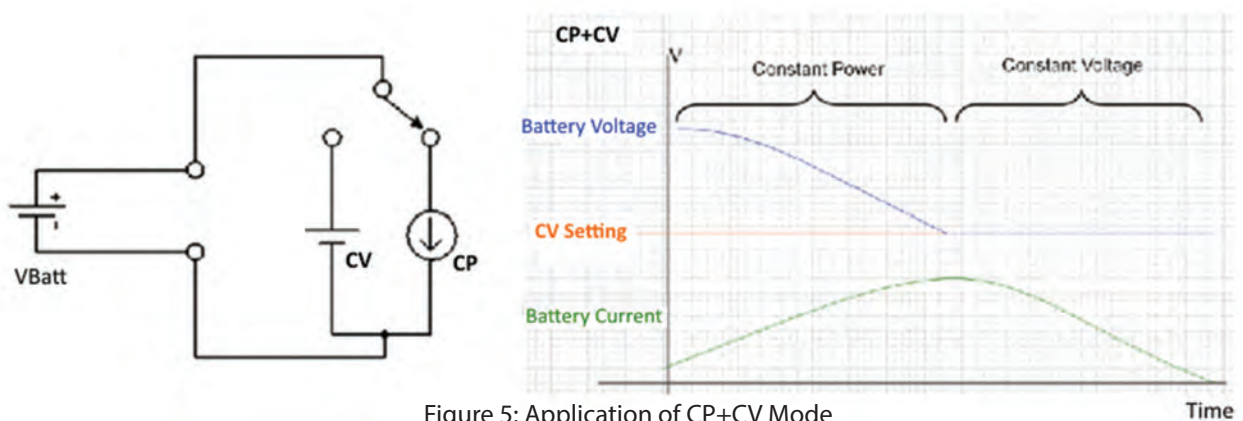


Figure 5: Application of CP+CV Mode

## CP+CV Operation Mode

In CC + CP mode of operation, the electronic starts discharging the battery using a constant amount of power drain as determined by the CP set point. Once the battery voltage sags to the CV set point, the load transitions from CP mode to CV mode to maintain the discharged state battery voltage.

Operation in CP+CV mode is very straightforward as the load automatically switches from CP constant power mode discharge mode to CV constant voltage mode. This prevents the battery from being damaged due to excessive discharging. This mode of operation is illustrated in Figure 5.

### Operation Procedure

- Load input terminals are connected to the DUT
- Change to CP mode and setting CP power setting.
- Press Limit key to set the CV voltage and the display will show "Add.CV".
- Press START key to start up the CP+CV test, and press "STOP" key to stop CP+CV test.
- Set CC+CV or CP+CV upper limit voltage, Middle 5 digit LCD display Add.CV, right 5 digit LCD display unit is "V", The Add.CV set range from 0.00 V to 600.00V step 0.01V by rotating the Setting knob.



## CC+UVP Operation Mode

In CC + UVP (Under Voltage Protection) mode of operation, the electronic starts discharging the battery using in constant current mode with a current drain determined by the CC set point. Discharging will continue till the battery reaches the Under voltage protection point as set by the UVP set point. At this point, the total amount of Ampere Hours drawn from the battery will be display in AH and no more discharging occurs.

Operation in CC+UVP mode is very straightforward as the load automatically switches from CC constant current mode discharge mode to OFF mode. This prevents the battery from being damaged due to excessive discharging. This mode of operation is illustrated in Figure 6.

### Operation Procedure

1. To setting loads current on Constant current (CC) mode.
2. Press Config key to BATT1 and setting the UVP voltage.

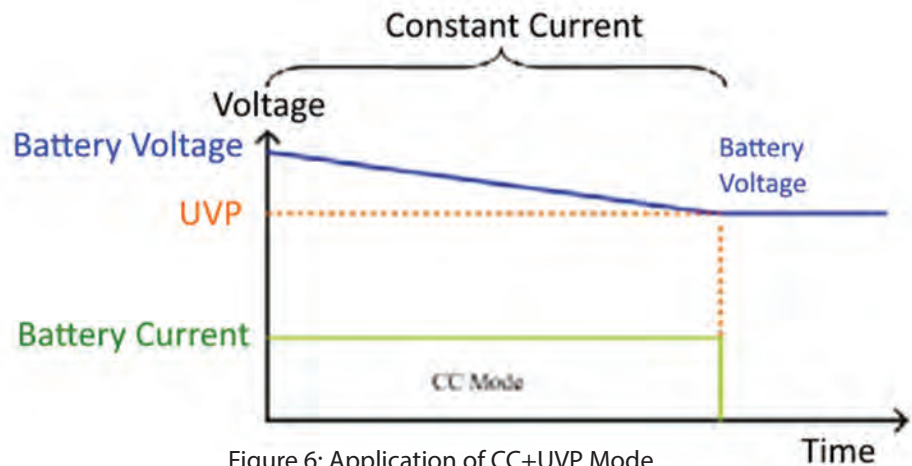


Figure 6: Application of CC+UVP Mode

3. Press Start key to do the BATT1 (CC+UVP) test

When the battery voltage is less than UVP (under voltage protect) set value, the Load ON LED is off to indicate Load off status, and the total discharge stored energy is displayed in Ampere Hours (Ah).

**Note:** when in remote control mode, the front panel does not display the total discharge capacity but this information can be queried over the bus.

## CP+UVP Operation Mode

In CP + UVP (Under Voltage Protection) mode of operation, the electronic starts discharging the battery using a constant amount of power drain as determined by the CP set point. Discharging will continue till the battery reaches the Under voltage protection point as set by the UVP set point. At this point, the total amount of Ampere Hours drawn from the battery will be display in AH and no more discharging occurs.

Operation in CP+UVP mode is very straightforward as the load automatically switches from CP constant power mode discharge mode to OFF mode. This prevents the battery from being damaged due to excessive discharging. This mode of operation is illustrated in Figure 7.

### Operation Procedure

1. To setting loads power on Constant Power (CP) mode.
2. Press Config key to BATT1 and setting the UVP voltage.
3. Press Start key to do the BATT1 (CP+UVP) test

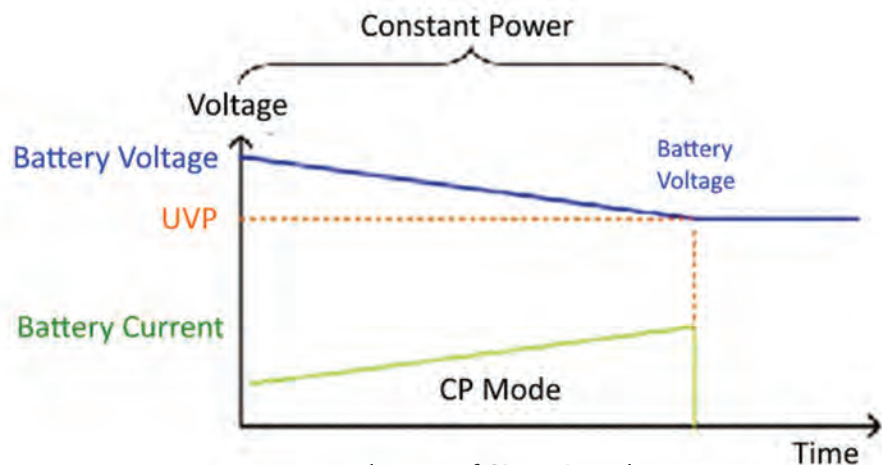


Figure 7: Application of CP+UVP Mode

When the battery voltage is less than UVP (under voltage protect) set value, the Load ON LED is off to indicate Load off status, and the total discharge stored energy is displayed in Ampere Hours (Ah).

## Other Discharge Modes

In addition to the four battery discharge test modes described above, the 5VP electronic loads also support pre-set discharge time interval setting, pulse and ramp current discharge modes.

## Timed Discharge Mode

Timed discharge mode uses pre-set discharge time interval setting to discharge the battery using either a constant current or constant power level.

### Operation Procedure

1. Set the load current or power in Constant Current (CC) or Constant Power (CP) mode.
2. Press Config key to BATT3 and set the discharge time.
3. Press the "Start" key to start the BATT3 (CC/CP + discharge time) test. When testing loads on of Constant current (CC) or Constant Power (CP) mode, when the set discharge time expires, the load turns off and displays the end battery voltage.

## Pulse and Ramp Discharge Modes

Discharge current can also be programmed to follow a set step or ramp pattern as needed. A sample pulse discharge current waveform is shown in Figure 9. A sample ramp discharge current waveform is shown in Figure 10.

These specific discharge profiles can be used to simulate actual driving conditions dependent battery discharge profiles to test and evaluate battery performance and life-span.

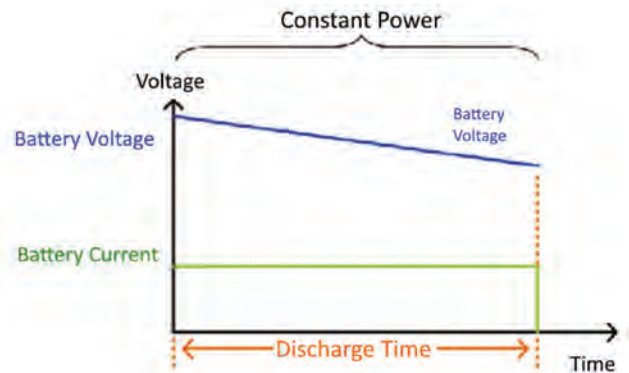


Figure 8: Timed Battery Discharge Mode

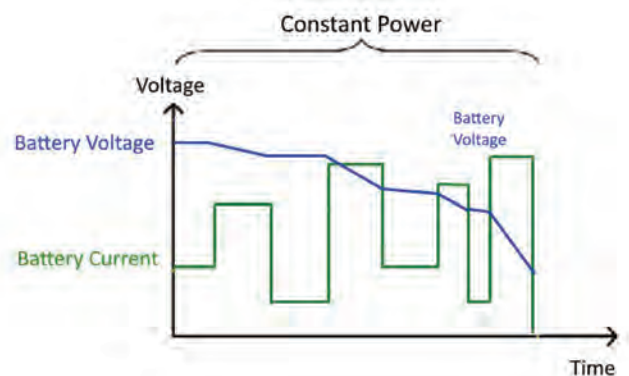


Figure 9: Pulsed Current Battery Discharge Mode

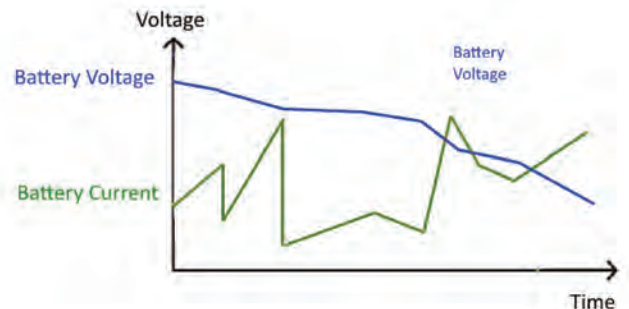


Figure 10: Ramp Current Battery Discharge Mode

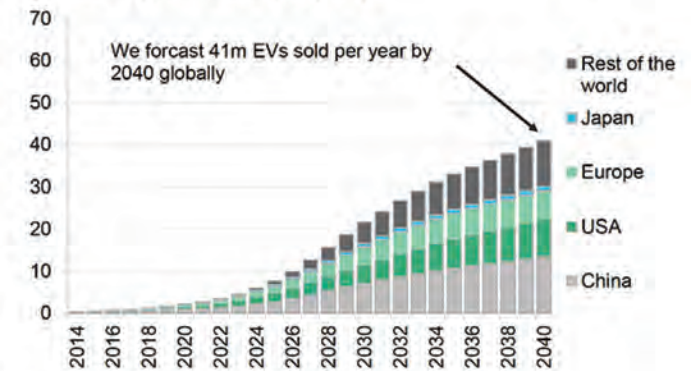
# APPLICATION NOTE

## Conclusion

Forecasts on future sales of all electric vehicles are pointing to a growing need for large battery packs. The chart in Figure 11 shows demand will continue to increase over the next 25 years. These batteries must be carefully designed and thoroughly tested to meet customer expectations for driving range, durability and above all safety. Without the right tools and equipment, testing of these batteries will be inadequate to meet these goals.

Adaptive Power Systems is committed to being a partner with you when it comes to power test equipment. Feel free to contact us to discuss your requirements.

Figure 11: BNEF global EV sales forecast by geography, 2015–2040 (m vehicles per year)



Source: Bloomberg New Energy Finance, Marklines

## Service and Support

Adaptive Power Systems' customer support is second to none. Our Customer Support Program provides the training, repair, calibration, and technical support services that our customers value. So, in addition to receiving the right test equipment, our customers can also count on excellent support before, during and after the sale. With company owned support and service centers around the world, support is never far away.

**New Product Warranty:** AC Sources & Loads: 1 year, DC Power Supplies: 2 years.

Complete calibration and repair services are offered at our US, European and Chinese manufacturing facilities (see contact info below). Calibrations are to original factory specifications and are traceable to NIST (National Institute of Standards and Technology).

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