CHARLIE - Computerized Hardware Autonomous Robotic LId-rEtrieval

Operating Manual

Designed and Manufactured by

Pomelo Inc.

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1. Introduction

Pomelo Inc's CHARLIE is a complex robot designed to simulate the safe removal of mines in the form of metal can lids. It is capable of navigating a roughly 3x3 metre area and collecting up to five can lids. CHARLIE is lightweight and portable, boasting the highest quality plywood and retractable parts.

CHARLIE is a fully autonomous robot and can travel over its area smoothly and efficiently, requiring no commands from the user when it is in the process of sweeping for can lids. CHARLIE's greatest strength is its ability to drive in a straight line and react dynamically to obstacles using advanced ultrasonic sensing technology paired with a sophisticated algorithm as executed by the integrated Arduino MEGA.

Once a can lid is collected, CHARLIE maps its location and updates an LED 7-segment display so that the number of can lids that have been found will be readily visible. When all lids are collected, CHARLIE returns to its initial position. CHARLIE is also capable of transmitting live video feed from a mounted camera directly to your computer screen.

Whether you're a hobbyist or an educator, CHARLIE is the right robot for you. We hope CHARLIE serves you well in all your pursuits.

Wishing you all the best in your can lid-collecting endeavours,

The team at Pomelo Inc.

2. Systems

2.1 Arduino

The mine detector is controlled by an Arduino Mega 2560 Microcontroller rev3, located at the centre of the cart, inside the electrical box. The MEGA runs a program from the computer and is responsible for all of CHARLIE's signal processing. It is powered by 2 6V battery packs, one wired to CHARLIE's servo motors, camera, sensors, metal detector, load cell and LED display. The other powers the arduino solely. The Arduino communicates wirelessly with the computer through a bluetooth module.

2.2 Metal detector

There are two metal detectors, (8.5±.1)cm in diameter, located on the bottom of CHARLIE. The detector coils are placed adjacent to one another. Each coil is made of nineteen windings of wire wrapped around a cardboard circle, and connected to a circuit consisting of a

10nF capacitor and 220Ω resistor in series. The changing inductance due to ferromagnetic metal affects the potential over the capacitor, which is read by a digital pin on the Arduino MEGA. The metal detectors are calibrated such that they will only respond to the significant change in inductance due to the can lids. Because the search coils cover the entire width of the cart, CHARLIE cannot miss a can lid as it passes over. The detectors should be calibrated at the beginning with no metal with a radius of the detector coils for five seconds to avoid false detection readings. As CHARLIE passes over a can lid, the metal detectors signal to the Arduino to commence pickup procedures.

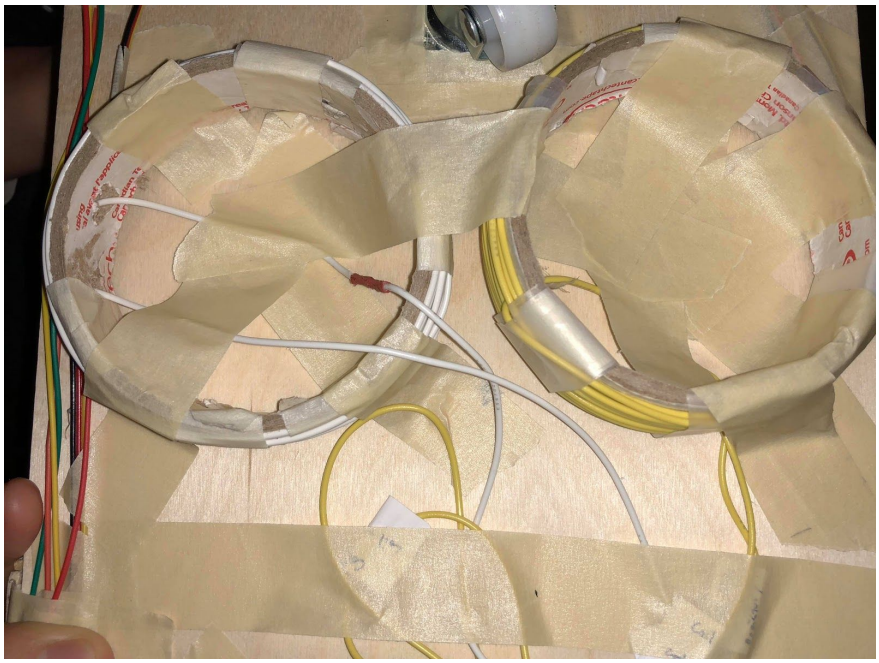

Fig 1. *Metal detectors located on the underside of CHARLIE.*

2.3 Pickup arm

This component consists of a HS-422 non-continuous servo motor attached to a (15±.1)cm arm extension, terminating in a permanent magnet. When it contacts the can lids, the magnet will pick up the lid and swing to the detachment mechanism on the front of CHARLIE. The servo motor is attached on the bottom of CHARLIE to ensure that it is within range of any can lids. It rests upright to ensure compactness. Once metal is detected, CHARLIE will rotate left and right to retrieve any can lids in the detection range of the detector coils. During turns, it will extend for the duration of the maneuver to retrieve lids near the turns. After retrieving a lid, it will swing up through a narrow gap, catching the can lid on the detachment mechanism. While the servo continues to swing the remaining distance, the can lid will be caught in the box surrounding the detachment mechanism, guiding the lid to the load cell where the retrieval can

be confirmed through a change in weight. The pickup arm will then return to its initial position. The pickup arm can also be retracted for storage and portability purposes.

Fig 2. Retractable arm (foreground) and detachment mechanism. *The pickup arm swings backwards, catching the can lid on the slit seen in the above photo, dropping it onto the load cell platform, and returning to rest.*

2.4 Load Cell

The collection of can lids is confirmed when they are deposited onto the load cell by the pickup arm. The load cell consists of the straight bar TAL220 and the load cell amplifier HX711. The TAL220 is located between the bottom of the cart and the platform where the can lid will be deposited. The load cell is first zeroed to nullify any existing force on the load cell platform from the structure of the detachment mechanism. When a can lid falls on the platform, the force is translated into an electrical signal. The load cell measures the change in weight based on changes

in electrical resistance proportional to the force applied on the load cell. These signals are amplified by the HX711, which allows the Arduino to detect changes in weight. The load cell works in conjunction with the LED display to indicate the number of can lids that have been retrieved. CHARLIE will only indicate the presence of an additional can lid through a change in mass.

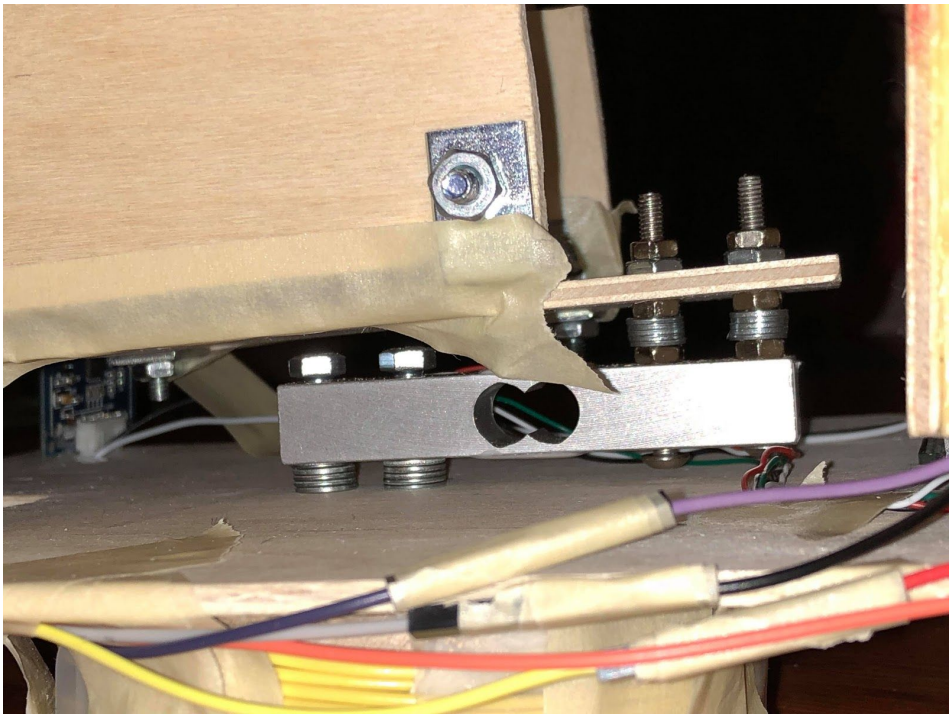

Fig 3. *Load cell under the can lid depository.*

2.5 Seven-Segment LED Display

The seven-segment LED display is made with a soldered anode seven-segment display. Two 330Ω resistors are used to limit the current and a wire is soldered to each of the ten pins on the display to connect them to the corresponding ten digital pins on the Arduino MEGA. All of the connections are soldered onto a PCB board. The LED display can represent digits from zero to nine, though only zero to five is required. When the load cell detects a significant increase in weight, the Arduino MEGA updates the number on the LED display.

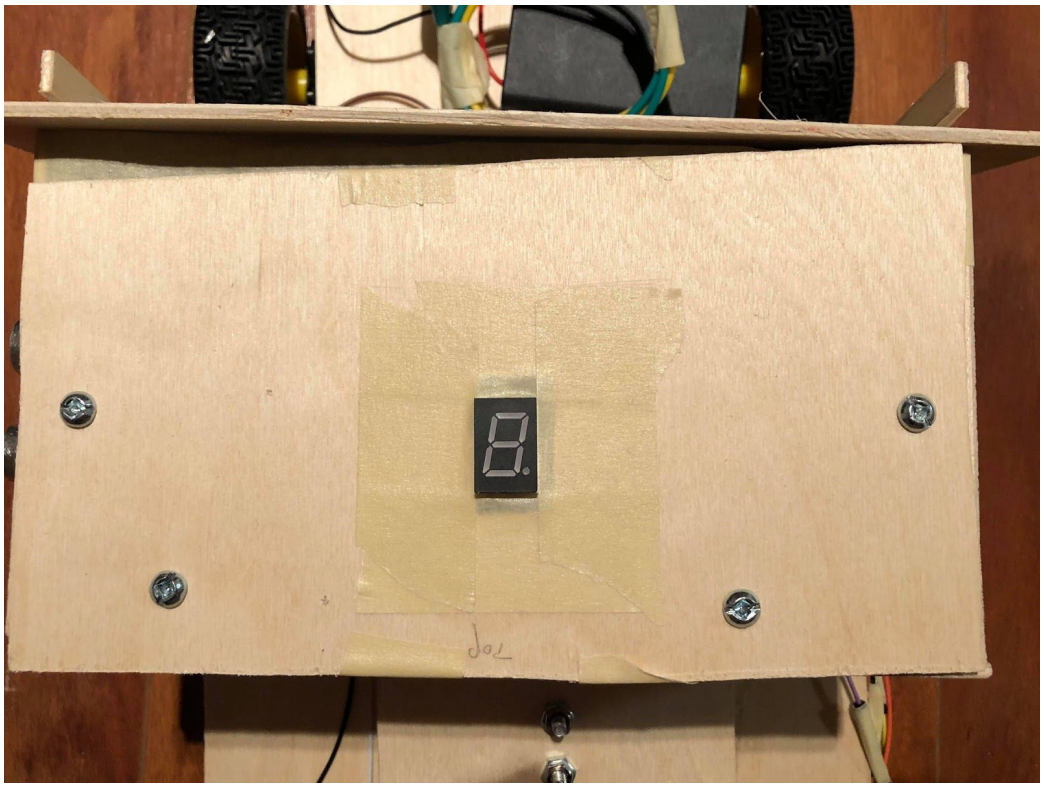

Fig 4. *LED display located on top of wiring box.*

2.6 Motion

CHARLIE follows a programmed path within a 3x3 metre area. Beginning in one corner, it completes a circular outer loop around the perimeter of the area to cover the blind spots that occur during the inner path. The inner path is a back and forth motion through rows of 20 cm each. When CHARLIE completes the final row, it will return to its original location.

HC-SR04 Ultrasonic Range Sensors are located on CHARLIE's front and right sides to allow it to operate in a controlled fashion and track its location from the computer. The sensors send and receive frequencies that echo off obstacles in its path. By calculating the time elapsed between the signal's departure and return, the distance to the walls can be calculated. Aside from recording the path through the computer, the sensors are used to control the cart's path. The front sensor is used primarily to detect walls for the 90 and 180 degree turns in the inner and outer paths. The right side sensor detects the distance from the side walls to maintain proper path separation, ensuring CHARLIE sweeps the entire area.

Fig 5. *An ultrasonic sensor located on the side for wall detection.*

Two FeeTech FS5103R Continuous Servo Motors power CHARLIE's back wheels to facilitate its movement. The servos allow CHARLIE to drive forward, backwards, and adjust its path so that it drives in a freaking straight line. The free moving castor wheel at the front provides strong structural support. As a freely rotating wheel, it provides CHARLIE with a 360 degree range of motion. The servo speeds are continuously adjusted, allowing CHARLIE to move slowly enough for the metal detectors to detect the presence of can lids while keeping a straight path.

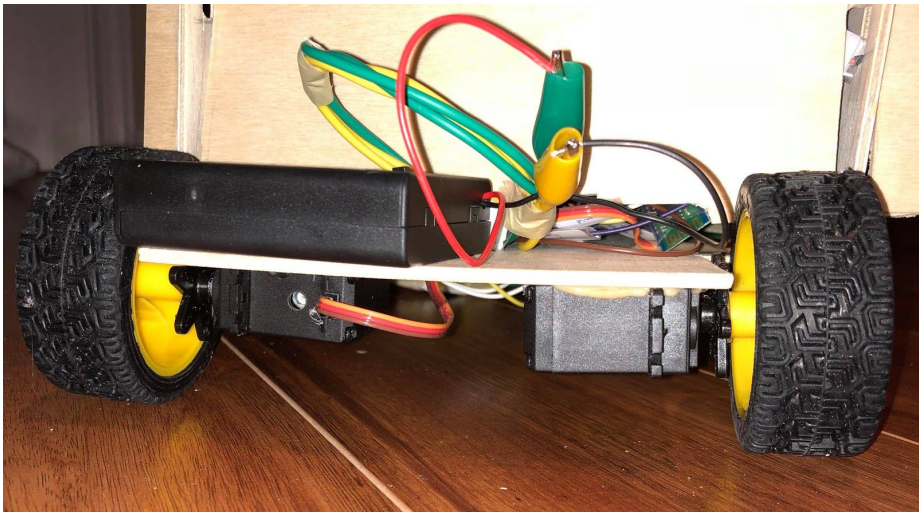

Fig 6. *Back wheels powered by continuous servo motors, attached to 6V battery pack.*

2.7 Camera

A UART TTL Serial Digital Camera Module was used in conjunction with the Adafruit VC0706 Arduino Camera Library for ease of use. It is set to take pictures of the smallest size possible, 160x120, which can be changed to a maximum size of 640x480. Note that larger photo sizes yield larger file size, and thus the transmission time of the photo from Arduino to PC via Bluetooth is longer.

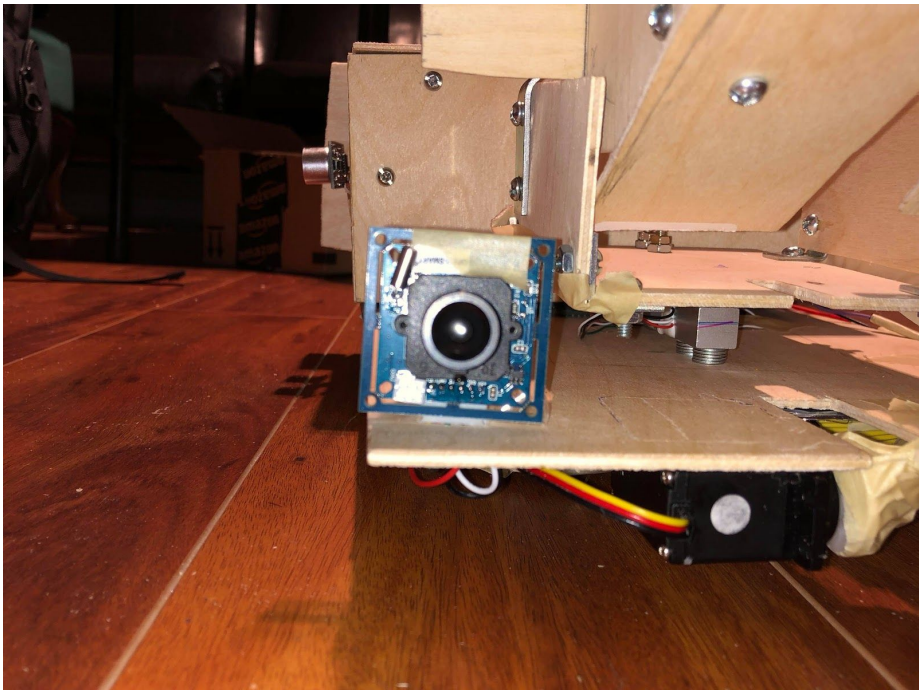

Fig 7. *Camera mounted on front of CHARLIE*

3. Software

The Arduino language is used to interface with the microcontroller using the Arduino IDE. The “Mine Detector Viewer” is programmed in Processing, so both Arduino and Processing should be installed on the system. This software is optimized for Windows 8.1 and 10 and Mac OS X Lion or newer. However, it may also be supported by older operating systems.

The program, “Mine Detector Viewer”, is programmed in Processing and displays data from a wireless Bluetooth connection with CHARLIE. Processing offers a library for serial communication, employed with the HC-05 Arduino Bluetooth module, that is installed alongside the Processing IDE. To view the video feed from the UART TTL Serial Digital Camera Module, the Processing IDE, found at processing.org, must be installed. If the previous requested data is already received, the program sends a request to the Arduino for either a picture or for situational data every 500 milliseconds. The pictures are sewn together to imitate a very low frame rate video and the situational data, which includes the position of the car and the position of the can lids, will be mapped onto a drawing of the arena. If the Arduino does not respond within 3 000 milliseconds to the computer’s request, the “Mine Detector Viewer” is programmed to move to the next request. The baud rate for serial communication is set to match the baud rate of the Bluetooth module. The maximum functioning baud rate, used on both the PC and the Arduino for maximum performance, is 230 400 bps.

SCREENSHOT

Fig 8. Mine Detector Viewer window.

4. Setup

CHARLIE is designed to function specifically in a smooth 3x3 metre region enclosed by boundaries at least 20 cm in height. CHARLIE works best when starting from a corner. Ensure that an ultrasonic sensor is facing the closest wall to the side of the cart for optimal performance.

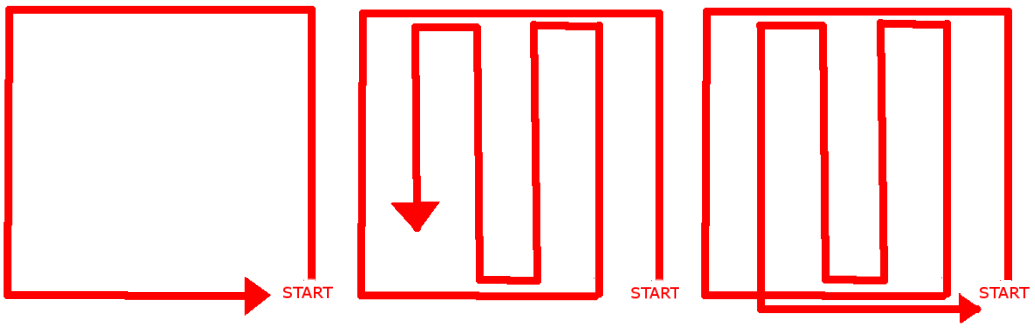

Fig 9. Programmed path. *CHARLIE will follow the above path. Exact number of turns not accurately represented in diagrams.*

5. Operation

1. Pair your computer with the Bluetooth module.

    Pair your computer with "HC-05" with the password "1234". After pairing, determine the outgoing COM port for communication between the PC and the Bluetooth Module through device manager. This COM port will be known as COMx hereafter. In the Processing code for the Mine Detector Viewer, replace "COM5" with COMx. This will allow the program to read data sent by the Arduino.

2. Turn on the battery pack.

    Find the switch for the battery pack located near the wheels and turn it on. Hold CHARLIE in the air, wheels facing down, for the next step.

3. Upload the program to the Arduino MEGA.

    Open the file titled **MineDetectorFinal.ino** and open it in the Arduino IDE on your computer. Make sure you have a stable bluetooth connection and press the upload button on the corner of the window. Wait a few moments for the code to compile and upload.

4. Place the cart and open Mine Detector Viewer.

    The servo motors will activate and the wheels will begin to turn. Carefully place CHARLIE in its starting position, taking care to align the HC-SR04 Ultrasonic Sensors with the wall. Run the Mine Detector Viewer program in order to view a video feed from CHARLIE as well as CHARLIE's location.

5. Release the cart.

    CHARLIE is now fully autonomous and will follow a preprogrammed path, reacting to obstacles and approaching walls. Observe the LED display on the cart that will update

each time a lid is picked up. The ultrasonic sensors will measure CHARLIE's position, which will be plotted on a map.

6. Troubleshooting

No issues regarding the operation of CHARLIE is expected as CHARLIE has been extensively tested. However, there are rare instances where problems may arise.

A troubleshooting guide has been compiled for common errors and malfunctions that may occur. The back of the box containing all the electrical components is designed for easy removal. The wires have also been labelled and easy to read, so readjustment of wires will not be a difficulty.

Problem	Solution
CHARLIE does not start	Replace batteries in battery pack. Ensure that the motors are switched on. Check that the wires are not damaged or disconnected. Reupload the program.
CHARLIE does not detect metal	Ensure that the floor flat and the search coils of the metal detector are almost touching the floor. Recalibrate the metal detector by holding it still in an area clear of metal for five seconds.
CHARLIE gives false metal readings	Ensure that the path area is flat and clear of any metal besides the can lids. Recalibrate the metal detector by holding it still in an area clear of metal for five seconds.
CHARLIE does not follow designated path	Ensure the ultrasonic sensors wires are not damaged or disconnected. Reupload the program. Ensure code detaches motors before taking an reading and reattaches motors afterwards. Ensure surrounding environment does not contain sound absorbing materials.
CHARLIE does not deposit can lids in proper location	Ensure can lids are no greater than 3 inches in diameter. Check the battery pack and replace the batteries if necessary.
LED display does not update	Check the connections and resistors behind the

	7-segment display. Ensure the load cell is functioning properly and tighten the screws attaching the load cell to the cart body.
Load cell does not detect weight change	Ensure connections to load cell amplifier is secure. Ensure platform attachments to strain gauge are secure.
COMx not found error when running the Mine Detector Viewer	COMx in the Mine Detector Viewer code should be specified to be the outgoing port for communication between the HC-05 module and the PC. Open the device manager and ensure the proper port was selected.
COMx busy when running the Mine Detector Viewer	The Bluetooth module must be powered in order for the program to form a Bluetooth connection between the computer and the Arduino. If the problem arises while the Bluetooth module is powered, turn off the battery pack, then turn it back on for the Bluetooth module to reset..
Array Index Out of Bounds when running the Mine Detector Viewer.	The program is unexpectedly reading in data sent to COMx from previous runs. Rerun the program and the port should be cleared and operational.

7. FAQ

Q. ***Can CHARLIE operate in an area that is not 3x3m?***

A. Yes. The code can be modified for CHARLIE to operate in an area larger or smaller than 3x3m. It would work on the same principle. However, bear in mind that if the area is too large, the distance from CHARLIE to the wall will eventually exceed the range of the ultrasonic sensor and CHARLIE will lose its ability to correct its path into a straight line.

Q. ***In what environments can CHARLIE function?***

A. CHARLIE will only perform reliably on a flat, metal-less surface, preferably indoors. It must be enclosed by four boundaries with a height of at least 20 cm. CHARLIE will not

work on uneven terrain. It will also only work in a rectangular enclosure as the program cannot create a path for other polygonal areas.

Q. ***Will CHARLIE function starting from any location?***

A. Given the nature of CHARLIE's programming, the ideal location to begin is in one of the four corners. If placed in an arbitrary location, the adjustment mechanisms may not be able to adapt to the new situation.

Warnings

To prevent injury or death, please heed the following warnings.

- Do not attempt to supply CHARLIE with more batteries than specified in the manual.
- Always turn CHARLIE off when not in use.
- Do not use with damaged or leaking batteries
- Keep away from wet surfaces.
- Keep away from strong magnets.
- Keep away from extreme heat.
- CHARLIE is not a toy. Not intended for children under the age of 12.
- Wires pose a choking hazard and should be handled with caution. Keep out of reach of young children.

Warranty and Contact

Limited two hour warranty (For AP Physics purposes only).

Please call customer service at 1-DO-NOT-CALL, or send an email to donotemaileither@company.com. Allow four to five business days for no response.

When used within the specific criteria specified in the APC Lab Manual, and in accordance with the Operating Manual, CHARLIE is warranted against any defects, structurally and electrically, within two hours of purchase. During this warranty period, Pomelo Inc. will, at maximum cost to the customer, replace or correct any such defect.

This warranty does not cover improper maintenance, damage due to misuse, use beyond the specific purpose for which the product was initially designed, and resales of the product.