Vinga Cycle Rig System

A Battery Testing Solution for Brompton Bicycle

AB0005-132, rev A

www.wireflow.se

The Challenge

Brompton Bicycle builds one of the most iconic foldable commuter bikes and is Britain’s largest bike producer.

Upon introduction of their first electric bike to the market, they needed a top-of-the line battery testing solution. Initially, the requirement was to test three packs, but the solution had to be scalable for easy upgrade to up to ten packs.

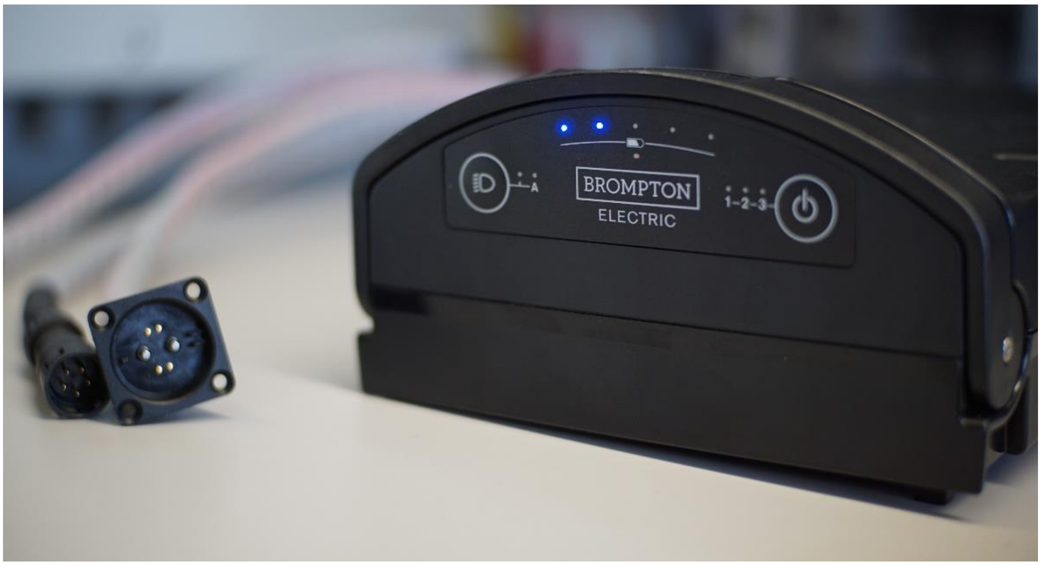


Figure 1 - Brompton Electric battery pack

Figure 2 - Brompton Bicycle

The Solution

WireFlow has extensive experience both with automated testing equipment and li-ion batteries. We designed a flexible and compact test solution that could scale up according to Brompton’s future needs.

The core of the WireFlow solution is the Valand battery test and measurement software, running on a cRIO industrial controller which controls bi-directional PSUs (Power Supply Units) for charge and discharge.

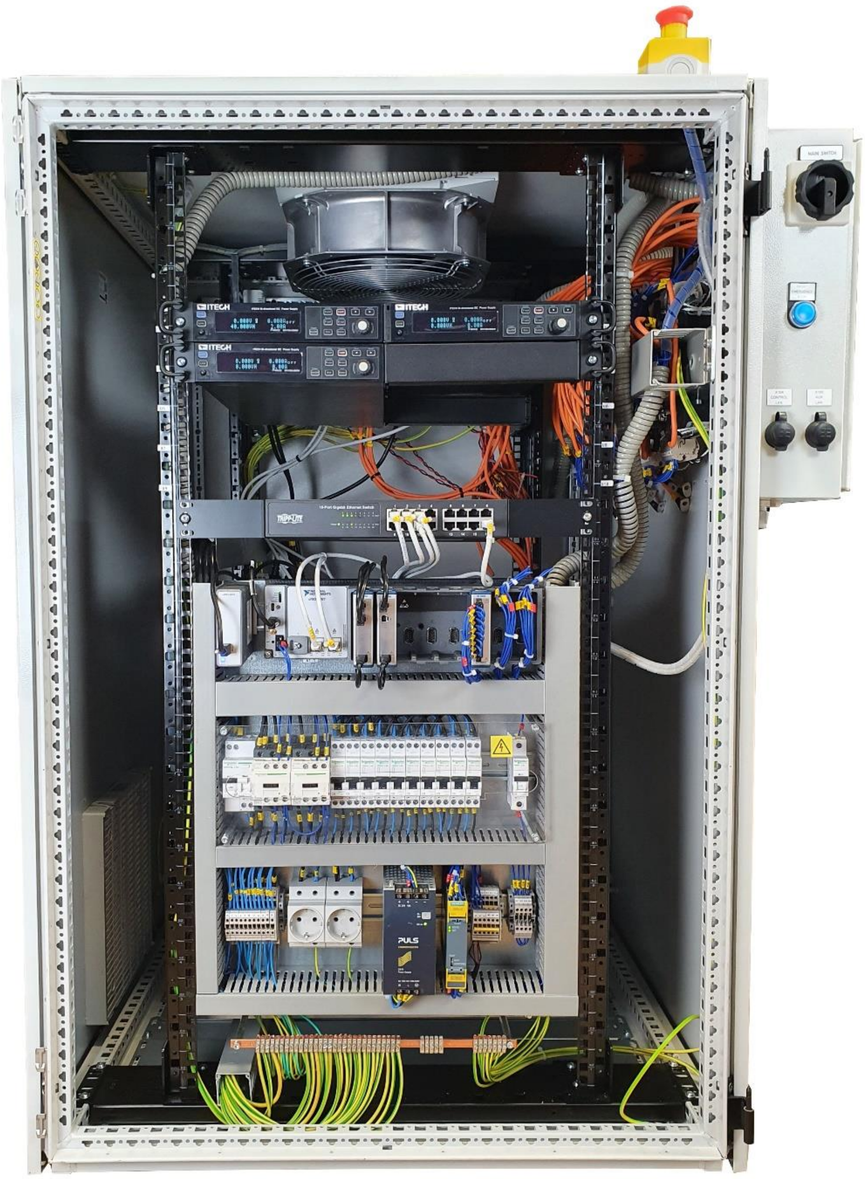


Figure 3 - Vinga System in Cabinet

Energy efficient hardware with Real-time control

The system is controlled by a cRIO-9057 industrial controller that executes test sequences for each battery pack independently. A remote PC is used for management and configuration of the system.

Each battery pack has a set of dedicated hardware (CAN-bus, PSU and contactors).

The CAN-bus is used for interfacing with the battery pack Battery Management System (BMS). State variables and error messages can be read, logged, and acted upon via this interface. It is also possible to send commands to the battery pack.

The network-controlled PSUs are regenerative and used for charge and discharge. By using regenerative PSUs, the power from discharge is fed back to the grid, minimizing heat dissipation thus allowing a more compact size, as well as lowering the operating cost. Ten packs can be tested with a cabinet only 1200mm (24HE) high.

As with many bicycle battery packs, the charge and discharge connectors are separate. To fully automate the testing and to control the current path, the system has a set of contactors that can switch between connectors when needed.

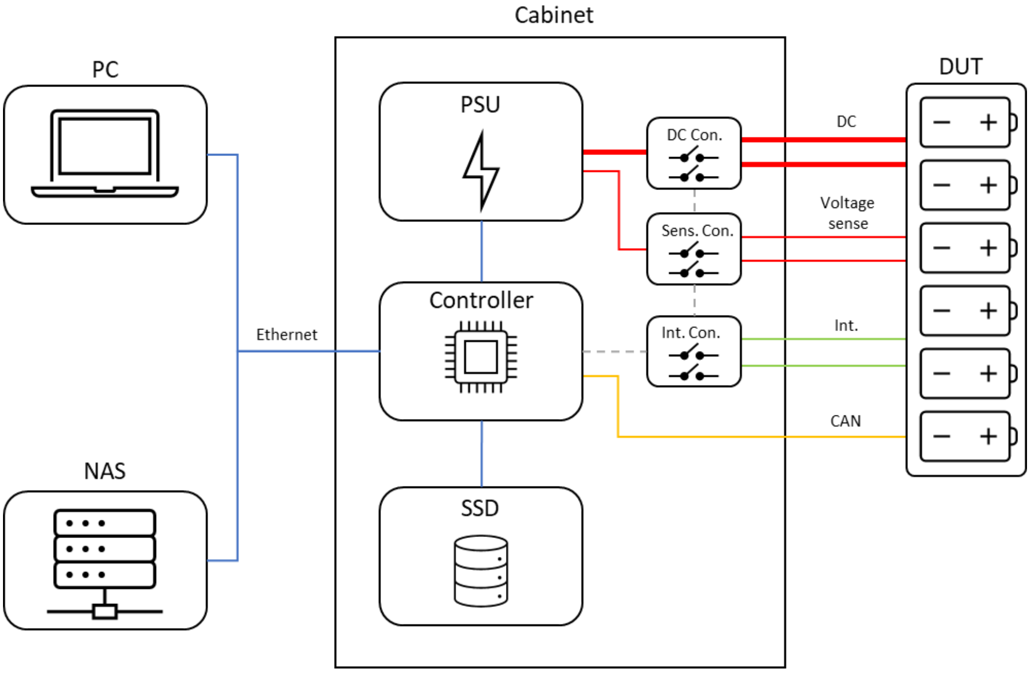


Figure 4 - Hardware Architecture (showing single battery pack)

Cables between cabinet and DUT (Device Under Test) are terminated in a side-mounted connection box with terminal blocks. With this solution, it's possible to vary the cabling for each pack individually so that multiple battery types can be tested concurrently.

A common emergency switch button is mounted on the cabinet if there is a need to quickly terminate testing.

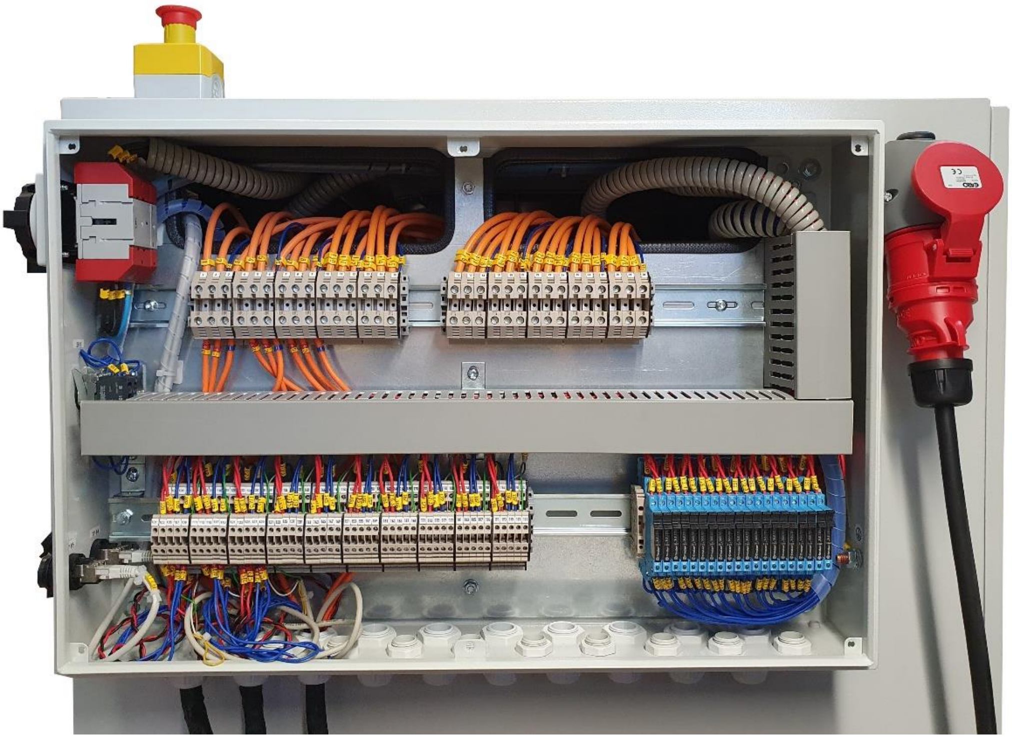


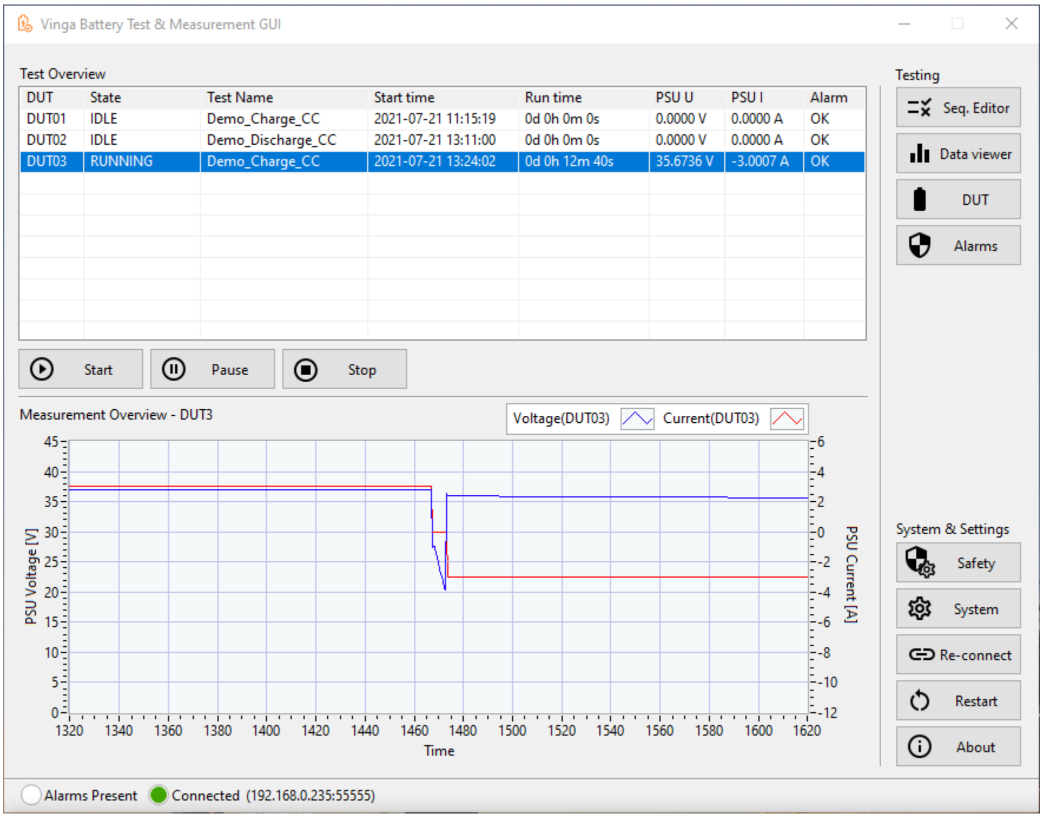
Figure 5 - IO-box for connecting the battery pack

Valand Software – Flexible with Scripting

The Valand software is based on WireFlow's Valand framework. The Valand framework has been developed specifically for battery cell and battery pack testing.

Valand software is purpose-built for running test sequences for battery cells and packs. A test sequence is made up of test script building blocks, which during execution write variable values and test results to log files.

It is also possible to control the system manually without using sequences or scripts. This can be useful both during script development and for simple testing.



Vinga Battery Test & Measurement GUI

Test Overview

DUT	State	Test Name	Start time	Run time	PSU U	PSU I	Alarm
DUT01	IDLE	Demo_Charge_CC	2021-07-21 11:15:19	0d 0h 0m 0s	0.0000 V	0.0000 A	OK
DUT02	IDLE	Demo_Discharge_CC	2021-07-21 13:11:00	0d 0h 0m 0s	0.0000 V	0.0000 A	OK
DUT03	RUNNING	Demo_Charge_CC	2021-07-21 13:24:02	0d 0h 12m 40s	35.6736 V	-3.0007 A	OK

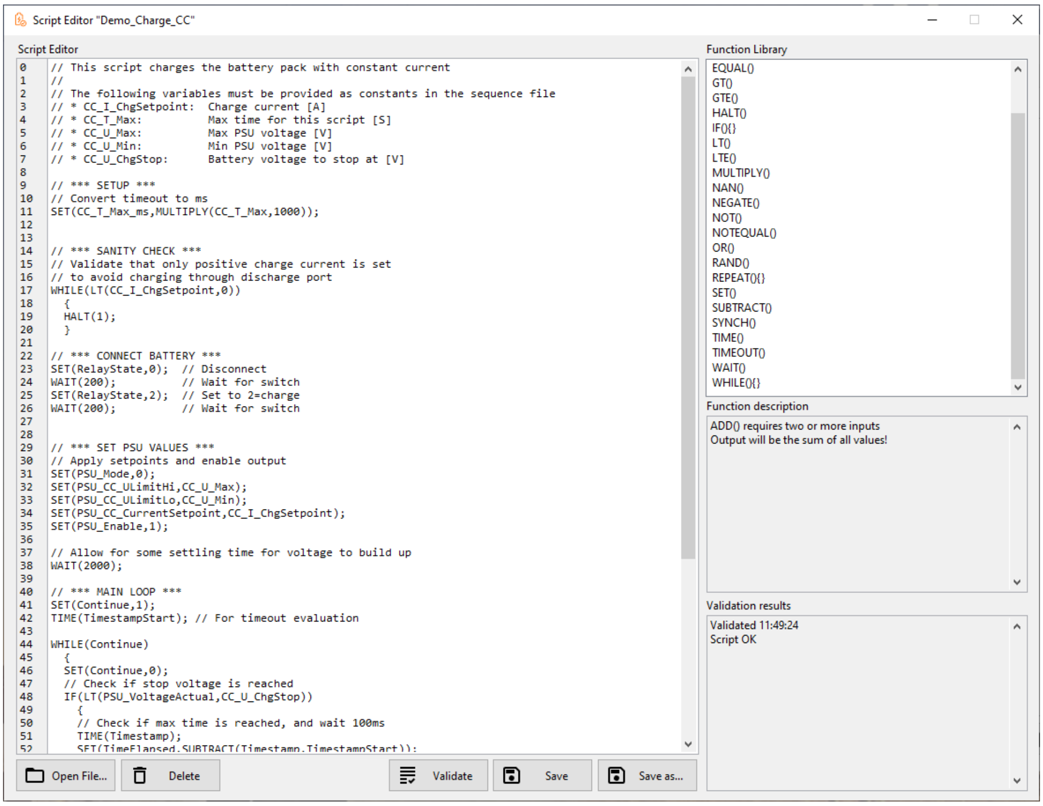
○ Alarms Present ● Connected (192.168.0.235:55555)

Figure 6 - Main Window on PC

The test scripts are written in a C-style language where the test engineer can implement almost any type of test that the hardware supports. The built-in editor can validate the script for syntax errors and has a help module describing each function.

All battery pack variables are available in the scripting environment, so it is easy to set up tests with almost any criterion. Tests can range from simple test cases such as cycling between pre-defined SOCs or voltage levels whilst doing coulomb counting; to more advanced test cases such as triggering error conditions for validation of BMS software logic.

Scripts and sequences are stored in a library for easy re-use.



```
// This script charges the battery pack with constant current
//
// The following variables must be provided as constants in the sequence file
// * CC_I_ChgSetpoint:  Charge current [A]
// * CC_T_Max:          Max time for this script [S]
// * CC_U_Max:          Max PSU voltage [V]
// * CC_U_Min:          Min PSU voltage [V]
// * CC_U_ChgStop:      Battery voltage to stop at [V]

// *** SETUP ***
// Convert timeout to ms
SET(CC_T_Max_ms,MULTIPLY(CC_T_Max,1000));


// *** SANITY CHECK ***
// Validate that only positive charge current is set
// to avoid charging through discharge port
WHILE(LT(CC_I_ChgSetpoint,0))
  {
  HALT(1);
  }

// *** CONNECT BATTERY ***
SET(RelayState,0);  // Disconnect
WAIT(200);          // Wait for switch
SET(RelayState,2);  // Set to 2=charge
WAIT(200);          // Wait for switch


// *** SET PSU VALUES ***
// Apply setpoints and enable output
SET(PSU_Mode,0);
SET(PSU_CC_ULimitHi,CC_U_Max);
SET(PSU_CC_ULimitLo,CC_U_Min);
SET(PSU_CC_CurrentSetpoint,CC_I_ChgSetpoint);
SET(PSU_Enable,1);

// Allow for some settling time for voltage to build up
WAIT(2000);

// *** MAIN LOOP ***
SET(Continue,1);
TIME(TimestampStart); // For timeout evaluation

WHILE(Continue)
  {
  SET(Continue,0);
  // Check if stop voltage is reached
  IF(LT(PSU_VoltageActual,CC_U_ChgStop))
    {
    // Check if max time is reached, and wait 100ms
    TIME(Timestamp);
    SET(TimeElapsed,SUBTRACT(Timestamp,TimestampStart));
```

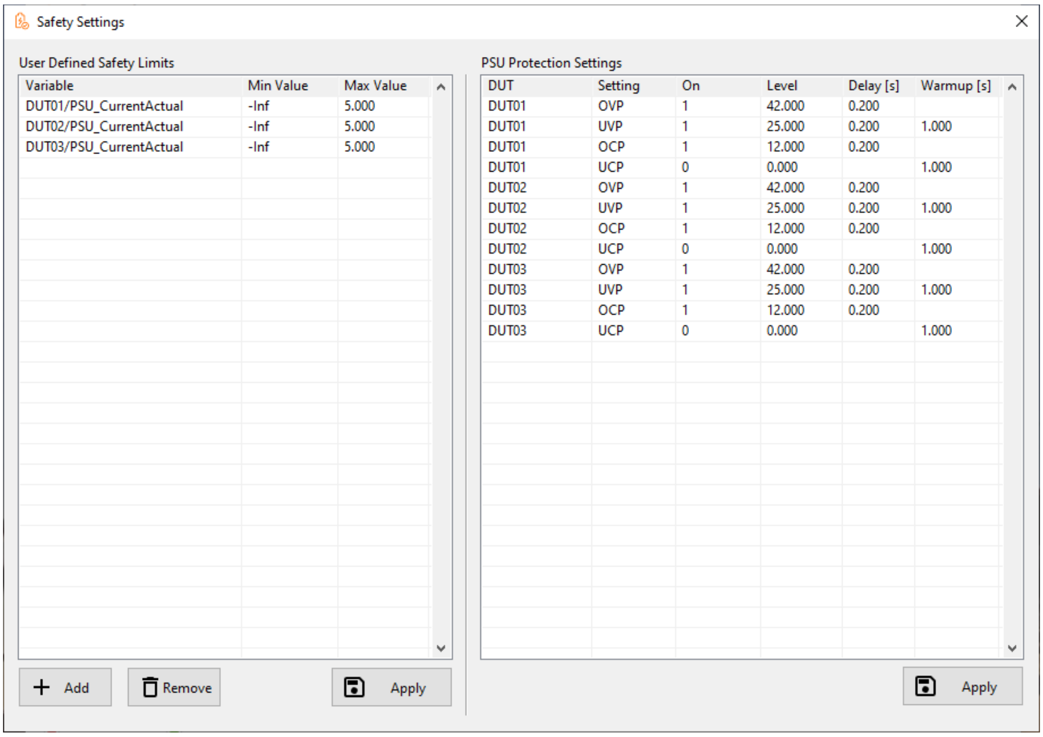
ADD() requires two or more inputs
Output will be the sum of all values!

Validated 11:49:24
Script OK

Figure 7 – Test Script Editor on PC

The system includes an independent alarm function that runs in the background, which monitors variables selected by the user and compares them with user-defined limits. If a value is outside the limits, the system is put in a safe state (PSU disabled and contactors disengaged). Thus, if a test sequence is running, it will be halted. Alarm limits can be set individually per battery pack and the failure of any one pack won't affect the others.

The alarm function can also be used to configure OVP (Over Voltage Protection), UVP (Under Voltage Protection), OCP (Over Current Protection) and UCP (Under Current Protection) for each battery pack.



User Defined Safety Limits

Variable	Min Value	Max Value
DUT01/PSU_CurrentActual	-Inf	5.000
DUT02/PSU_CurrentActual	-Inf	5.000
DUT03/PSU_CurrentActual	-Inf	5.000

PSU Protection Settings

DUT	Setting	On	Level	Delay [s]	Warmup [s]
DUT01	OVP	1	42.000	0.200	
DUT01	UVP	1	25.000	0.200	1.000
DUT01	OCP	1	12.000	0.200	
DUT01	UCP	0	0.000		1.000
DUT02	OVP	1	42.000	0.200	
DUT02	UVP	1	25.000	0.200	1.000
DUT02	OCP	1	12.000	0.200	
DUT02	UCP	0	0.000		1.000
DUT03	OVP	1	42.000	0.200	
DUT03	UVP	1	25.000	0.200	1.000
DUT03	OCP	1	12.000	0.200	
DUT03	UCP	0	0.000		1.000

Figure 8 - Alarm Settings