ELECTRONIC TEST & POWER SYSTEMS

G5-BATSIM

HIGH VOLTAGE MODULAR BATTERY EMULATORS

POSITIVE PROBLEM SOLVING

G5-BATSIM systems are provided with advanced simulation software to accurately batteries. Modules are stackable to 3kV/6MW with mains recycling.

Nearly all relevant electrical characteristics are programmable, including the number of cells, energy capacity, cut off limits, chemistry type and nominal voltage. Each power dense module has an extensive feature set which includes programmable PID parameters and an inbuilt 8 channel recording scope. Adjustable power and resistance limits are provided. Optional remote control interfaces are available including high-speed CAN and a touchscreen HMI.

- Advanced Battery Emulation Software
- Two Current Ranges for Higher Accuracy
- Mixed Power Nominals in Master-Slave
- Sink/Source Voltages up to 3000V
- Programmable Ripple up to 10kHz
- Ultra-Fast Dynamic Behaviour

CONTENTS

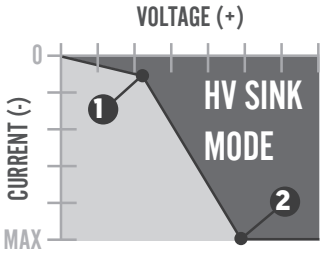
STANDARD MODELS

SELECTION TABLE

Part Number	Maximum Power	Q1 Source Voltage	Q4 Sink Voltage	Current Range	Internal Resistance Range
G5-BATSIM 18-500-108	18kW	0 to 500Vdc	3 to 500Vdc*	0 to ±108A	0 to 5000mΩ
G5-BATSIM 18-1000-54	18kW	0 to 1000Vdc	5 to 1000Vdc*	0 to ±54A	0 to 18000mΩ
G5-BATSIM 27-500-162	27kW	0 to 500Vdc	3 to 500Vdc*	0 to ±162A	0 to 3000mΩ
G5-BATSIM 27-1500-54	27kW	0 to 1500Vdc	8 to 1500Vdc*	0 to ±54A	0 to 27000mΩ
G5-BATSIM 36-500-216	36kW	0 to 500Vdc	3 to 500Vdc*	0 to ±216A	0 to 2500mΩ
G5-BATSIM 36-1000-108	36kW	0 to 1000Vdc	5 to 1000Vdc*	0 to ±108A	0 to 10000mΩ
G5-BATSIM 54-500-324	54kW	0 to 500Vdc	3 to 500Vdc*	0 to ±324A	0 to 1500mΩ
G5-BATSIM 54-1000-162	54kW	0 to 1000Vdc	5 to 1000Vdc*	0 to ±162A	0 to 6000mΩ
G5-BATSIM 54-1500-108	54kW	0 to 1500Vdc	8 to 1500Vdc*	0 to ±108A	0 to 14000mΩ

* The maximum current that can be taken derates as the voltage reduces beneath the lower level. Please see below for more details.

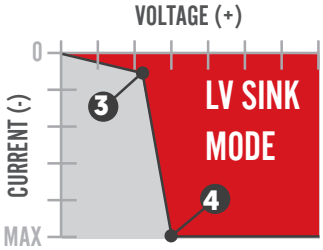
The maximum current that can be taken derates at low voltages. As standard the G5-BATSIM operates in HV Sink Mode when operating as a DC load. In this mode the user can sink full current from 3% V_{NOM} to 100% V_{NOM}, according to the maximum power. The HV Sink Mode operating range is indicated in dark grey.



Part Number	Point 1: 10% I_{MAX} (HV Mode)	Point 2: 100% I_{MAX} (HV Mode)
G5-BATSIM 18-500-108	8V / 10.8A	15V / -108A
G5-BATSIM 18-1000-54	15V / 5.4A	30V / 54A
G5-BATSIM 27-500-162	8V / 16.2A	15V / -162A
G5-BATSIM 27-1500-54	23V / 5.4A	45V / 54A

Part Number	Point 1: 10% I_{MAX} (HV Mode)	Point 2: 100% I_{MAX} (HV Mode)
G5-BATSIM 36-500-216	8V / -21.6A	15V / -216A
G5-BATSIM 36-1000-108	15V / -10.8A	30V / -108A
G5-BATSIM 54-500-324	8V / -32.4A	15V / -324A
G5-BATSIM 54-1000-162	15V / -16.2A	30V / -162A
G5-BATSIM 54-1500-108	23V / -10.8A	45V / -108A

If you require to sink higher currents at lower voltages, then setting a maximum voltage between 10V to 166V switches the G5-BATSIM to Low Voltage mode. The values possible at 100% I_{MAX} and 10% I_{MAX} are provided below. Lower voltages are possible with further current derating. The LV Sink Mode operating range is indicated in red.



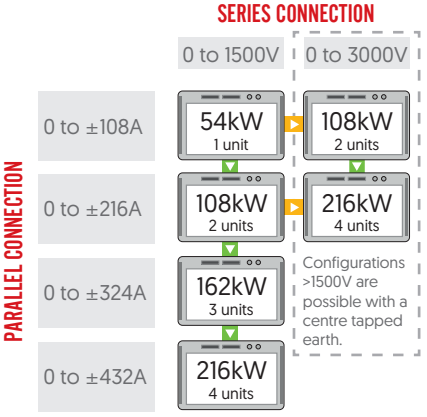
Part Number	Point 3: 10% I_{MAX} (LV Mode)	Point 4: 100% I_{MAX} (LV Mode)
G5-BATSIM 18-500-108	2V / 10.8A	3V / -108A
G5-BATSIM 18-1000-54	2V / 5.4A	5V / 54A
G5-BATSIM 27-500-162	2V / 16.2A	3V / -162A
G5-BATSIM 27-1500-54	3V / 5.4A	8V / 54A

Part Number	Point 3: 10% I_{MAX} (LV Mode)	Point 4: 100% I_{MAX} (LV Mode)
G5-BATSIM 36-500-216	2V / -21.6A	3V / -216A
G5-BATSIM 36-1000-108	2V / -10.8A	5V / -108A
G5-BATSIM 54-500-324	2V / -32.4A	3V / -324A
G5-BATSIM 54-1000-162	2V / -16.2A	5V / -162A
G5-BATSIM 54-1500-108	3V / -10.8A	8V / -108A

MODULARITY (MASTER/SLAVE)

G5-BATSIM modules can be arranged in series, parallel or matrix array configurations up to 6MW. Each module is able to operate independently, so that systems can be reconfigured, expanded or broken up as needs dictate. Inbuilt system comms allow users to switch between various set-ups. It is possible to connect models with different nominal powers in an asymmetric parallel or series configuration, as long as each module has the same nominal voltage. For example, an 18kW/500V/±108A and 54kW/500V/±324A module can be connected together to in parallel to create a 72kW/500V/±432A system.

The modular approach is useful for research teams who regularly test different sized power devices. The diagram shows all the possible combinations with four 54kW/1500V modules. Slave modules in a multi-unit system do not have BatSim software installed as standard.



ELECTRONIC TEST & POWER SYSTEMS

OPTIONS TABLE

OPTIONS

CODE	DESCRIPTION
	FORM FACTOR AND ENCLOSURES
/LR	Integration into a 19" lab rack
/FC	Integration into a flightcase
	INPUT
/FILTER	Front panel air filter and frame arrangement providing G3 filtration efficient for ≥10um particles
	INTERFACES AND CONTROL
/HMI	Lockable touchscreen HMI providing front panel control and measurement
/CANMP	Multi-protocol CAN interface with up to 100 user configurable messages
	SOFTWARE/SOFT TOOLS
/TFE	Integrated function generating engine for time based programming, including sweep function
/APP	Integrated function generating engine with application area (parametric) programming
/BATSIM	GUI simulating battery characteristics with adjustable parameters (option for slave modules only, installed as standard to master module)
/BATCONTROL	Energy storage and drive cycling GUI
/SASCONTROL	Solar array simulation GUI (includes /AAP option)
	SAFETY AND PROTECTION
/ISR	Integrated Safety Relay, e-stop interface for shutdown to EN ISO 13849-1:2015, Performance Level c
/PACOB	Protection against accidental contact of the AC terminal block
/RPP	Automatic voltage matching with reverse polarity protection
/XCD	AC safety discharge circuit discharging AC lines to <60V in <1s of AC power loss, required to meet EN 62477-1 for AC plug connections

FORM FACTOR AND ENCLOSURES

STANDARD FEATURES

TECHINCAL DATA	
Module Dimensions (Without Terminals)	19" × 672mm (W × D), a full cabinet integration service is available on request
Module Height	4U (18kW models), 7U (27kW/36kW models), 10U (54kW models)
Weight	50kg (18kW models), 77kg (27kW models), 87kg (36kW models), 121kg (54kW models)
Basic Construction	IP 20 (up to IP 54 when mounted in a cabinet)

Each G5-BATSIM is built into a 19" rackmounting case as standard. Units can be treated to a laboratory rack or flight case integration. Common options include mains cables, passive indication of any residual DC voltage, isolation monitoring of DC cables and a panel mounted emergency stop. Switch panels with removable DC links can be fitted for modular systems. This simplifies the reconfiguration between series, parallel or independent use. Simple wheeled cabinets are also available.

4U 18kW MODULES

7U 27kW/36kW MODULES

10U 54kW MODULES

216kW CABINET INTEGRATION

OPERATING RANGES AND FEATURES (18kW/27kW MODELS)

STANDARD FEATURES

	G5-BATSIM 18-500-108	G5-BATSIM 18-1000-54	G5-BATSIM 27-500-162	G5-BATSIM 27-1500-54
Remote Voltage Sense	Programmable (stability/drift: ≤0.01%FS[4] | temperature coefficient: 0.007%FS/°C)			
Stability/Drift	Voltage: ≤0.01%FS[4] | Current: ≤0.01%FS[4]			
Temperature Coefficient	Voltage: 0.005%FS/°C[5] | Current: 0.005%FS/°C[5]			
Efficiency	Up to 96%			
Rise/Fall Time[6]: Voltage Step (0 to 90% V_{MAX}/ 90% P_{MAX})	≤170µs	≤180µs	≤170µs	≤170µs
Rise/Fall Time[7]: Current Step (-90% to 90% I_{MAX} at 33% V_{MAX}) 10% to 90% of step/settling time	25µs/180µs	25µs/150µs	20µs/190µs	25µs/190µs
Transient Response Time[8] (CV, Recovery Within 0.5% of Set Voltage)	≤200µs	≤110µs	≤200µs	≤150µs
Transient Response Time[9] (CC, Recovery Within 2% of Set Current)	≤250µs	≤300µs	≤250µs	≤290µs
Voltage Drop While Load Switching On	≤2% FS (-90% to 90% P_{MAX} at 90% V_{MAX} in HighCap mode) ≤4% FS (-90% to 90% P_{MAX} at 33% V_{MAX} in HighCap mode)			
Voltage Overshoot While Load Switching Off (90% to -90% P_{MAX} at 90% V_{MAX} in HighCap Mode)	≤2% FS			
Voltage Overshoot While Load Switching Off (90% to -90% P_{MAX} at 33% V_{MAX} in HighCap Mode)	≤4% FS	≤4% FS	≤5% FS	≤4% FS
Output Capacitance: X-capacitor LowCap	24µF	6µF	36µF	4µF
Output Capacitance: X-capacitor HighCap	444µF	111µF	666µF	74µF
Output Capacitance: Y-capacitor at DC	144nF	144nF	162nF	162nF
Ripple: Output Voltage Ripple (<1 MHz): Vrms, LowCap, Ohmic Load, 90% P_{MAX} 90% V_{MAX}, CV Mode	≤0.03% FS	≤0.05% FS	≤0.02% FS	≤0.03% FS
Ripple: Output Voltage Ripple (<1 MHz): Vrms, HighCap, Ohmic Load, 90% P_{MAX}, 90% V_{MAX}, CV Mode	≤0.01% FS	≤0.02% FS	≤0.01% FS	≤0.02% FS
Ripple: Output Current Ripple (<1MHz): Arms, LowCap, Ohmic Load, 90% P_{MAX}, 90% I_{MAX}, CC Mode	≤0.05% FS	≤0.05% FS	≤0.05% FS	≤0.03% FS
Noise: (20kHz to 20MHz) : Vpp, LowCap, Ohmic Load, 90% P_{MAX}, 90% V_{MAX}, CV Mode	≤0.02% FS	≤0.2% FS	≤0.15% FS	≤0.15% FS
Noise: (20kHz to 20MHz) : Vpp, HighCap, Ohmic Load, 90% P_{MAX}, 90% V_{MAX}, CV Mode	≤0.1% FS			

[1] At 25°C ambient temperature, constant line conditions. [2] With a constant resistive load in LowCap mode.
[3] Constant voltage mode, recovery within 0.5% SetValue at 30% V_{MAX}/100% V_{MAX}, with a resistive load in HighCap mode.
[4] 8h after 1h warm up time at constant line input, load and temperature. [5] At constant line and load conditions.
[6] Voltage set-value step, constant resistance load, LowCap mode. [7] Current set-value step, constant voltage, LowCap mode.
[8] 0 to 90% P_{MAX} load step at 90% V_{MAX}. Assuming an ohmic load in HighCap mode.
[9] 45 to 90% P_{MAX} load step at 90% I_{MAX}. Assuming an ohmic load in LowCap mode.

OPERATING RANGES AND FEATURES (18kW/27kW MODELS)

STANDARD FEATURES

	G5-BATSIM 18-500-108	G5-BATSIM 18-1000-54	G5-BATSIM 27-500-162	G5-BATSIM 27-1500-54
HMI Touchpanel Meter Resolution	0.01V/0.01A	0.1V/0.01A	0.01V/0.01A	0.1V/0.01A
Output Discharge to <60V	Active discharge enabled: <1s Active discharge disabled: <60s (500V models) | <75s (1000V models) | <90s (1500V models)			
Static Accuracy[10]: Power at I_{MAX} 1kHz Filter	0.03% typ. FS			
Static Accuracy[10]: voltage	0.01% typ. FS	0.01% typ. FS	0.01% typ. FS	0.016% typ. FS
Static Accuracy[10]: Current Full Range 1kHz Filter	0.025% typ. FS			
Static Accuracy[10]: Current Low Range (-10% to 10% FS) 1kHz Filter	0.003% typ. FS			
Static Accuracy[10]: Resistance at I_{MAX} 1kHz Filter	0.03% FS	0.025% FS	0.03% FS	0.03% FS
Pulsating Load: HighCap	30% I_{MAX} at 3kHz, 26% I_{MAX} at ≥ 5kHz (max. load ripple current sine, max. amplitude)			
Pulsating Load: LowCap	46% I_{MAX} at 3kHz, 17% I_{MAX} at ≥5kHz (max. load ripple current sine, max. amplitude)			
Max. Ripple DC+ to PE / DC- to PE (Max. Allowed Ripple Vrms ≤1kHz: 1050 Vrms >1 kHz: [1.26×10⁶/f +5] Vrms)	≤1kHz: 1050Vrms 2kHz: 630Vrms 5kHz: 250Vrms 10kHz: 130Vrms 20kHz: 65Vrms 50kHz: 30Vrms 80kHz: 20Vrms			
Small Signal Modulation (Voltage Controller LowCap Mode)	Frequency (CV, CC): 0 to 10kHz Max. output voltage RMS sine at 10kHz: 0 to 5% FS Attenuation at 5kHz/10kHz, operating point: 90% V_{NOM} +5% V_{NOM} amplitude: 0.4dB/-6dB Phase lag analogue input to voltage out: 130µs			
Small Signal Modulation (Current Controller LowCap Mode)	Max. output amplitude current at 10kHz: 0 to 5% FS Attenuation at 5kHz/10kHz operating point: 90% I_{NOM} + 5% I_{NOM} amplitude: -1.8dB/-3.8dB Phase lag analogue input to current out: 110µs			
Sense Input Impedance While Operational	632kΩ	1212kΩ	632kΩ	1812kΩ
Sense Input Impedance - Voltage OFF (RPP Closed if Option Chosen)	632kΩ	1212kΩ	632kΩ	1812kΩ
Sense Input Impedance - Voltage OFF (Output Measurement Disconnected)	>10MΩ			
Ballast Resistor DC Power Port at Voltage OFF (no /RPP Option or RPP Closed)	37kΩ	140kΩ	25kΩ	210kΩ
Ballast Resistor DC Power Port at Voltage OFF (With Option /RPP, Output Measurement Disconnected and Voltage OFF Deactivated)	632kΩ	1212kΩ	632kΩ	1812kΩ
Ballast Resistor DC Power Port at Voltage OFF (With Option /RPP, Output Measurement Disconnected and Voltage OFF Activated)	>10MΩ			

[10] At 25° ambient temperature, constant line/load conditions normal distribution (k=2).

OPERATING RANGES AND FEATURES (36kW/54kW MODELS)

STANDARD FEATURES

	G5-BATSIM 36-500-216	G5-BATSIM 36-1000-108	G5-BATSIM 54-500-324	G5-BATSIM 54-1000-162	G5-BATSIM 54-1500-108
Remote Voltage Sense	Programmable (stability/drift: ≤0.01%FS[4] | temperature coefficient: 0.007%FS/°C)				
Stability/Drift	Voltage: ≤0.01%FS[4] | Current: ≤0.01%FS[4]				
Temperature Coefficient	Voltage: 0.005%FS/°C[5] | Current: 0.005%FS/°C[5]				
Efficiency	Up to 96%				
Rise/Fall Time[6]: Voltage Step (0 to 90% V_{MAX}/ 90% P_{MAX})	≤150µs	≤180µs	≤170µs	≤170µs	≤170µs
Rise/Fall Time[7]: Current Step (-90% to 90% I_{MAX} at 33% V_{MAX}) 10% to 90% of step/settling time	25µs/190µs	25µs/180µs	20µs/120µs	20µs/190µs	25µs/190µs
Transient Response Time[8] (CV, Recovery Within 0.5% of Set Voltage)	≤100µs	≤100µs	≤200µs	≤200µs	≤120µs
Transient Response Time[9] (CC, Recovery Within 2% of Set Current)	≤240µs	≤300µs	≤250µs	≤250µs	≤290µs
Voltage Drop While Load Switching On	≤2% FS (-90% to 90% P_{MAX} at 90% V_{MAX} in HighCap mode) ≤4% FS (-90% to 90% P_{MAX} at 33% V_{MAX} in HighCap mode)				
Voltage Overshoot While Load Switching Off (90% to -90% P_{MAX} at 90% V_{MAX} in HighCap Mode)	≤1.5% FS	≤2% FS	≤2% FS	≤2% FS	≤2% FS
Voltage Overshoot While Load Switching Off (90% to -90% P_{MAX} at 33% V_{MAX} in HighCap Mode)	≤4% FS	≤4% FS	≤5% FS	≤5% FS	≤5% FS
Output Capacitance: X-capacitor LowCap	48µF	12µF	72µF	18µF	8µF
Output Capacitance: X-capacitor HighCap	888µF	222µF	1332µF	333µF	148µF
Output Capacitance: Y-capacitor at DC	181nF	181nF	219nF	219nF	219nF
Ripple: Output Voltage Ripple (<1 MHz): Vrms, LowCap, Ohmic Load, 90% P_{MAX} 90% V_{MAX}, CV Mode	≤0.03% FS	≤0.03% FS	≤0.02% FS	≤0.03% FS	≤0.03% FS
Ripple: Output Voltage Ripple (<1 MHz): Vrms, HighCap, Ohmic Load, 90% P_{MAX}, 90% V_{MAX}, CV Mode	≤0.02% FS	≤0.02% FS	≤0.02% FS	≤0.02% FS	≤0.02% FS
Ripple: Output Current Ripple (<1MHz): Arms, LowCap, Ohmic Load, 90% P_{MAX}, 90% I_{MAX}, CC Mode	≤0.05% FS	≤0.05% FS	≤0.05% FS	≤0.05% FS	≤0.05% FS
Noise: (20kHz to 20MHz) : Vpp, LowCap, Ohmic Load, 90% P_{MAX}, 90% V_{MAX}, CV Mode	≤0.15% FS	≤0.15% FS	≤0.15% FS	≤0.15% FS	≤0.15% FS
Noise: (20kHz to 20MHz) : Vpp, HighCap, Ohmic Load, 90% P_{MAX}, 90% V_{MAX}, CV Mode	≤0.1% FS				

[1] At 25°C ambient temperature, constant line conditions. [2] With a constant resistive load in LowCap mode.
[3] Constant voltage mode, recovery within 0.5% SetValue at 30% V_{MAX}/100% V_{MAX}, with a resistive load in HighCap mode.
[4] 8h after 1h warm up time at constant line input, load and temperature. [5] At constant line and load conditions.
[6] Voltage set-value step, constant resistance load, LowCap mode. [7] Current set-value step, constant voltage, LowCap mode.
[8] 0 to 90% P_{MAX} load step at 90% V_{MAX}. Assuming an ohmic load in HighCap mode.
[9] 45 to 90% P_{MAX} load step at 90% I_{MAX}. Assuming an ohmic load in LowCap mode.

OPERATING RANGES AND FEATURES (36kW/54kW MODELS)

STANDARD FEATURES

	G5-BATSIM 36-500-216	G5-BATSIM 36-1000-108	G5-BATSIM 54-500-324	G5-BATSIM 54-1000-162	G5-BATSIM 54-1500-108
HMI Touchpanel Meter Resolution	0.01V/0.01A	0.1V/0.01A	0.01V/0.01A	0.1V/0.01A	0.1V/0.01A
Output Discharge to <60V	Active discharge enabled: <1s Active discharge disabled: <60s (500V models) | <75s (1000V models) | <90s (1500V models)				
Static Accuracy[10]: Power at I_{MAX} 1kHz Filter	0.03% typ. FS				
Static Accuracy[10]: voltage	0.01% typ. FS	0.01% typ. FS	0.01% typ. FS	0.01% typ. FS	0.016% typ. FS
Static Accuracy[10]: Current Full Range 1kHz Filter	0.03% typ. FS	0.025% typ. FS	0.03% typ. FS	0.025% typ. FS	0.025% typ. FS
Static Accuracy[10]: Current Low Range (-10% to 10% FS) 1kHz Filter	0.003% typ. FS				
Static Accuracy[10]: Resistance at I_{MAX} 1kHz Filter	0.03% FS				
Pulsating Load: HighCap	30% I_{MAX} at 3kHz, 26% I_{MAX} at ≥ 5kHz (max. load ripple current sine, max. amplitude)				
Pulsating Load: LowCap	46% I_{MAX} at 3kHz, 17% I_{MAX} at ≥5kHz (max. load ripple current sine, max. amplitude)				
Max. Ripple DC+ to PE / DC- to PE (Max. Allowed Ripple Vrms ≤1kHz: 1050 Vrms >1 kHz: [1.26×10⁶/f +5] Vrms)	≤1kHz: 1050Vrms 2kHz: 630Vrms 5kHz: 250Vrms 10kHz: 130Vrms 20kHz: 65Vrms 50kHz: 30Vrms 80kHz: 20Vrms				
Small Signal Modulation (Voltage Controller LowCap Mode)	Frequency (CV, CC): 0 to 10kHz Max. output voltage RMS sine at 10kHz: 0 to 5% FS Attenuation at 5kHz/10kHz, operating point: 90% V_{NOM} +5% V_{NOM} amplitude: 0.4dB/-6dB Phase lag analogue input to voltage out: 130µs				
Small Signal Modulation (Current Controller LowCap Mode)	Max. output amplitude current at 10kHz: 0 to 5% FS Attenuation at 5kHz/10kHz operating point: 90% I_{NOM} + 5% I_{NOM} amplitude: -1.8dB/-3.8dB Phase lag analogue input to current out: 110µs				
Sense Input Impedance While Operational	632kΩ	1212kΩ	632kΩ	1212kΩ	1812kΩ
Sense Input Impedance - Voltage OFF (RPP Closed if Option Chosen)	632kΩ	1212kΩ	632kΩ	1212kΩ	1812kΩ
Sense Input Impedance - Voltage OFF (Output Measurement Disconnected)	>10MΩ				
Ballast Resistor DC Power Port at Voltage OFF (no /RPP Option or RPP Closed)	19kΩ	74kΩ	13kΩ	51kΩ	112kΩ
Ballast Resistor DC Power Port at Voltage OFF (With Option /RPP, Output Measurement Disconnected and Voltage OFF Deactivated)	632kΩ	1212kΩ	632kΩ	1212kΩ	1812kΩ
Ballast Resistor DC Power Port at Voltage OFF (With Option /RPP, Output Measurement Disconnected and Voltage OFF Activated)	>10MΩ				

[10] At 25° ambient temperature, constant line/load conditions normal distribution (k=2).

OPERATING RANGES AND FEATURES

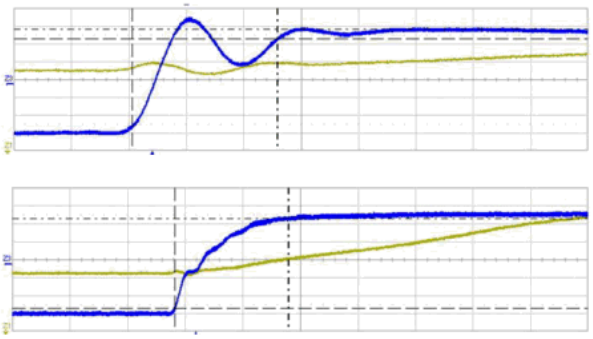
HIGHLIGHTED FEATURES

SENSE COMPENSATION

Sense plus terminals are built into the G5-BATSIM for the connection of sense wire which compensates for voltage drops in the load lines. This has a number of advantages over traditional sense. It is permitted to interrupt the load line during operation (voltage on). The maximum voltage drop compensation is adjustable. The voltage difference between G5-BATSIM output and sensing point is monitored. If a set limit is exceeded, the G5-BATSIM unit shuts off. This is particularly useful for applications with long cables often prone to unwanted voltage drops.

FAST DYNAMICS AND HIGH STABILITY

A current step between 90% sourcing to 90% sinking current can be as quick as 50µs, enabling high speed drives to be supplied. Advanced users have access to the controller settings enabling the response to be optimised for particular loads. This example shows a current step through quadrants. The upper trace shows the current transition is achieved in 50µs with a small overshoot before settling. The lower plot shows a more regulated response within 200µs. Voltage typically takes 100µs to recover within 0.5% of the set value. In multi-module systems the communication time between modules need to be considered.



SECOND CURRENT RANGE

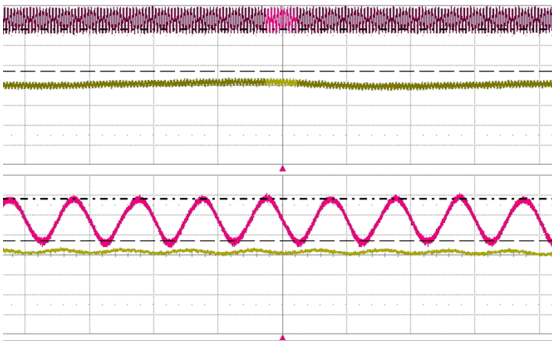
Each module features a second current range that can be built into systems to give better accuracy and resolution for low current applications. This is particularly useful when testing high voltage equipment, such as electric vehicle battery packs, which typically produce low currents.

SWITCHABLE OUTPUT CAPACITANCE

Switchable capacitance is provided within each G5-BATSIM module as standard and is used to optimise the DC filter depending on the application in which the systems are used. A low capacitance level provides fast dynamics in constant current for users who also want to charge/ discharge/ cycle energy storage devices. Switching to the higher cap value provides for smoother operation during hard load steps when operating in constant voltage. Typical applications include energy storage simulation for electric drive developments.

PROGRAMMABLE RIPPLE

By utilising the optional embedded function generator the user can set a current ripple at up to 10kHz. The magnitude can be up to 5% of the nominal system current. Depending on the impedance of the DUT the resulting voltage ripple can be calculated. The below example shows a 10kHz ripple generated using the function generator of the G5-BATSIM. A peak to peak current of 8A has been superimposed on a current of 100A. Alternatively, a ripple can be implemented from an external waveform generator via the analogue interface using a proportional

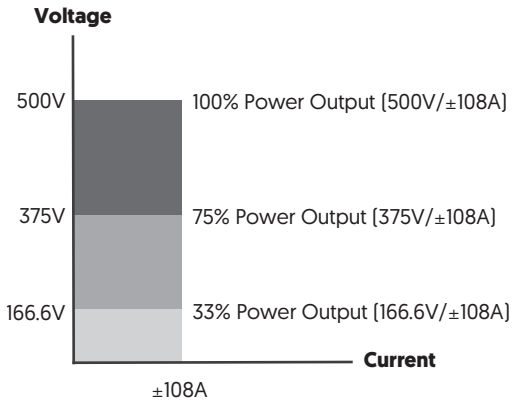


AUTORANGING CAPABILITY

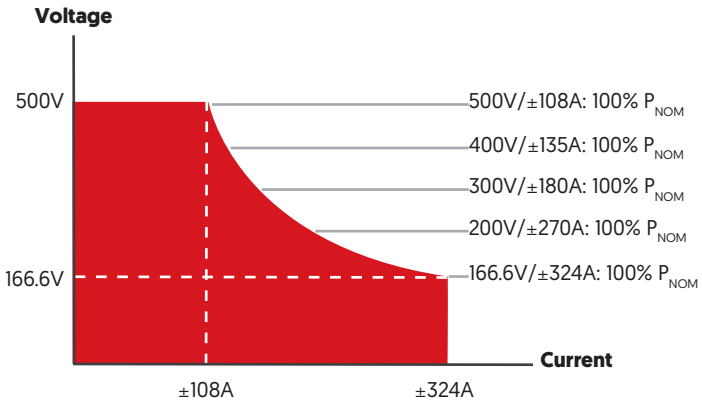
Every G5-BATSIM features an autoranging output. This allows many more voltage/current combinations at nominal power than a traditional bidirectional DC power system. An example of the difference is shown below using a G5-BATSIM 54-500-324.

Using one autoranging bidirectional PSU instead of several traditional battery simulators saves both cost and bench space. Despite the units offering such a large output range, they are still incredibly power dense. 54kW of output power is provided from 10U of rackmounting height.

TRADITIONAL 54kW/500V SYSTEM



G5-BATSIM 54kW/500V SYSTEM



OPERATING MODES

STANDARD FEATURES

	G5-BATSIM 18-500-108	G5-BATSIM 18-1000-54	G5-BATSIM 27-500-162	G5-BATSIM 27-1500-54
Operating Modes	Constant Voltage (0 to 100% of V_{MAX}) Constant Current (0 to ±100% of I_{MAX}) Constant Power (±5% to ±100% of P_{MAX})			
Internal Resistance Range	0 to 5000Ω	0 to 18000Ω	0 to 3000Ω	0 to 27000Ω
Programmable Load (CR Mode: R_{MAX} at V_{MAX}, R_{MIN} at V_{MIN})	0.1 to 1500Ω	0.5 to 7000Ω	0.05 to 1000Ω	0.5 to 10000Ω
Standard Interfaces	Analogue, Ethernet (up to 800 × 16 bit/s) & USB (up to 450 × 16 bit/s)			

	G5-BATSIM 36-500-216	G5-BATSIM 36-1000-108	G5-BATSIM 54-500-324	G5-BATSIM 54-1000-162	G5-BATSIM 54-1500-108
Operating Modes	Constant Voltage (0 to 100% of V_{MAX}) Constant Current (0 to ±100% of I_{MAX}) Constant Power (±5% to ±100% of P_{MAX})				
Internal Resistance Range	0 to 2500Ω	0 to 10000Ω	0 to 1500Ω	0 to 6000Ω	0 to 14000Ω
Programmable Load (CR Mode: R_{MAX} at V_{MAX}, R_{MIN} at V_{MIN})	0.05 to 500Ω	0.2 to 3500Ω	0.05 to 500Ω	0.1 to 2000Ω	0.3 to 5500Ω
Standard Interfaces	Analogue, Ethernet (up to 800 × 16 bit/s) & USB (up to 450 × 16 bit/s)				

HIGHLIGHTED FEATURE

INTERNAL RESISTANCE RANGE

Each module is built with a user programmable internal resistance range as standard. This makes the power supplies ideal for simulating the output of energy storage devices such as battery packs, fuel cell stacks and super capacitors. The exact range varies by module.

INPUT

STANDARD FEATURES

TECHNICAL DATA	
AC Line Voltage	3 × 380VAC to 480VAC ±10%
Line Frequency	50Hz/60Hz
Mains Connection Type	3L + PE (no neutral)
Rated Current	Nominal at 3 × 380VAC: 29ARMS (18kW units) | 44ARMS (27kW units) | 58ARMS (36kW units) | 87ARMS (54kW units) Nominal at 3 × 400VAC: 28ARMS (18kW units) | 42ARMS (27kW units) | 55ARMS (36kW units) | 83ARMS (54kW units) Nominal at 3 × 415VAC: 27ARMS (18kW units) | 40ARMS (27kW units) | 53ARMS (36kW units) | 80ARMS (54kW units) Nominal at 3 × 440VAC: 25ARMS (18kW units) | 38ARMS (27kW units) | 50ARMS (36kW units) | 75ARMS (54kW units) Nominal at 3 × 460VAC: 24ARMS (18kW units) | 36ARMS (27kW units) | 48ARMS (36kW units) | 72ARMS (54kW units) Nominal at 3 × 480VAC: 23ARMS (18kW units) | 35ARMS (27kW units) | 46ARMS (36kW units) | 69ARMS (54kW units)
Inrush Current	<33ARMS (18kW units) | <66ARMS (27kW units) | <66ARMS (36kW units) | <99ARMS (54kW units)
Power Factor	0.99 at P_{MAX}
THDi	≤0.03 at 90%P_{MAX}
Standby Power	31W (18kW units) | 51W (27kW units) | 52W (36kW units) | 71W (54kW units)
Protective Earth Conductor Current at 50Hz	According to IEC 60990: <7mA (18-36kW units) | <10mA (54kW units)
Input Filter Discharge to 60V	L-PE / L-L: <20s, with option /XCD: <1s

HIGHLIGHTED FEATURE

ACTIVE POWER FACTOR CORRECTION

G5-BATSIM modules have Active Power Factor Correction (PFC) circuit integrated into the input stage as standard. This enhances the overall efficiency of the modules across the output power range when compared to a unit that does not have active PFC. In practice, this means a significant lower peak current value, a decrease of RMS value of the phase current and less perturbations of other equipment running on the same grid.

The inbuilt active PFC is also ideal for operating the power supply from a generator. Generators tend to be sensitive against high current peaks, and their voltage controllers may have some stability problems with non-sinusoidal load currents. The active PFC feature forms a lowpass filter and therefore, both the repetitive current peaks and also the harmonic content is enhanced. This will help the generator system maintain a stable and reliable output.

OPTIONS

CODE	DESCRIPTION
/FILTER	Front panel air filter and frame arrangement providing G3 filtration efficient for ≥10um particles

HIGHLIGHTED OPTION

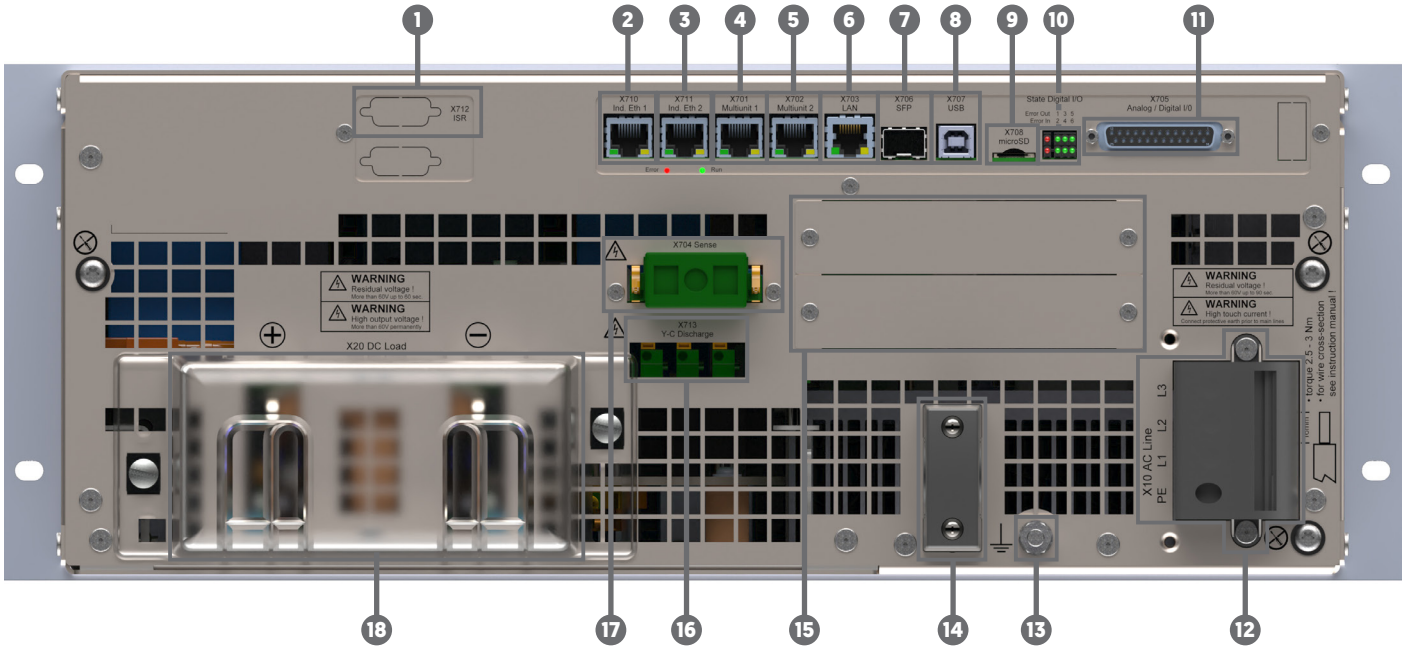
INPUT AIR FILTER (/FILTER)

The G5-BATSIM modules are designed to be operated within a clean laboratory environment. If there is the possibly that the environment will be less clean, then the optional front panel frame and air filter arrangement offer some additional protection. The standard filter material is rated in class G3. This class is effective at trapping a high proportion (90%) of particles ≥10um according to EN 779.

Air filters have proven beneficial in environments where there is the risk of some metal working potentially leading to swarf contamination. Please note that the units with or without air filters must not be operated in environments where fine conductive dust is present.

INTERFACES AND CONTROL

STANDARD INTERFACES



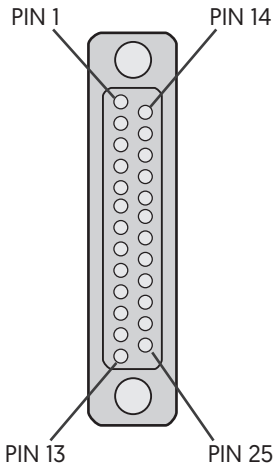
TECHNICAL DATA			
1	Optional	X712	Slot reserved for optional integrated safety relay (/ISR) interface.
2	Future Release	X710	Industrial Ethernet, e.g. EtherCat (release date TBC). This interface can be easily retrofitted in the field once released.
3	Future Release	X711	Industrial Ethernet, e.g. EtherCat (release date TBC). This interface can be easily retrofitted in the field once released.
4	Standard	X701	Multi-device communication interface SORTE protocol for parallel, series and matrix connection of modules.
5	Standard	X702	Multi-device communication interface SORTE protocol for parallel, series and matrix connection of modules.
6	Standard	X703	LAN interface (for external remote control).
7	Future Release	X706	Small form-factor pluggable (SFP) port which features a fibre optic card. Speeds up to 48kHz are planned via a direct connection to the G5-BATSIM's controller. The SFP will also a allow a planned integration with Aurora protocol to support real-time controllers such as Typhoon and OPAL-RT. This additional functionality will be easily enabled in the field once released.
8	Standard	X707	USB interface (for external remote control).
9	Future Release	X708	Unassigned micro SD slot, with the potential of module datalogging planned in the future. Release date yet to be confirmed.
10	Standard	State Digital I/O	Status indication of digital I/O status on X705.
11	Standard	X705	Proportional 0-10VDC isolated analogue interface (detailed overleaf).
12	Standard	X10	AC line side connection (L1, L2, L3, PE). Illustration shows optional AC protective cover (/PACOB).
13	Standard	-	Earthing terminal on unit chassis for additional earth connection.
14	Optional	-	Strain relief for AC cable.
15	Optional	-	Spare slots for optional interface cards (e.g. CANmp high speed 1kHz digital interface).
16	Standard	X713	Y-Cap discharge interface.
17	Standard	X704	Sense interface.
18	Standard	X20	DC terminals for connection to DUT with standard protective cover.

INTERFACES AND CONTROL

STANDARD ANALOGUE INTERFACE

An analogue interface is provided as standard which operates at 48kHz. The control port is configured as a Sub-D 25 female connector and is located on the rear panel. It allows output values to be set and read proportionally using a 0-10VDC analogue signal. Digital inputs and outputs enable various functions such as the interlock and output ON/OFF. A 10VDC reference is provided for analogue control. Digital functions are switched via a high/low signal. A 24VDC supply voltage is provided for these functions.

INPUT/OUTPUT DATA	
Number of Inputs/Outputs	4
Internal Resolution	16 bit
Input Accuracy	Bipolar range:±0.1%, Unipolar range: ±-0.2%
Output Accuracy	±0.2%
Input Filter	2nd order low pass filter, cut off frequency: 15kHz
Temperature Coefficient	0.02% FS/°C
Sampling/Update Rate	48kS/s
Output Settling Time	10µs (typical)
Input Voltage Range	-10V to +10V, -5V to +5V, 0V to 5V, 0V to 10V (selectable)
Absolute Max Input Voltage	±30VDC
Input Impedance	1MΩ (typical)
Output Voltage Range	-10V to +10V, -5V to +5V, 0V to 5V, 0V to 10V (selectable)
Max Output Current	20mA (short circuit proof)
Output Impedance	0.5Ω (typical)
Delay (Typical)	89µs (input to power out), 42µs (power out to analogue out)



PIN	SIGNAL	I/O	DESCRIPTION
1	AGND	Supp	Analogue ground for pins 2–4, 14–16
2	AIN1	AI	Voltage setpoint input 0–10VDC
3	AIN2	AI	Current setpoint input 0–10VDC
4	AOUT1	AO	Current feedback output 0–10VDC
5	AOUT2	AO	Power feedback output 0–10VDC
6	AOUT3	AO	Analogue reference voltage (+10VDC)
7	DGND	Supp	(Connected to pin 17) 0VDC DigIn; common ground for pins 8–9, 18–20, 24, 25
8	APP_DIGIO_4	DI/O	Digital input/ouput[3] 0-2VDC /10-28VDC Default function: Clear error
9	APP_DIGIN_6	DI	Digital input[3] 0-2VDC /10-28VDC Default function: Voltage ON
10	REL1_14	RO	Relay output 1 normally open
11	REL1_13	RO	Relay output 1 common
12	REL2_14	RO	Relay output 2 normally open
13	REL2_13	RO	Relay output 2 common

PIN	SIGNAL	I/O	DESCRIPTION
14	AIN3	AI	Power limit analogue input 0–10VDC
15	AIN4	AI	Load resistance reference value input 0–10 VDC
16	AOUT4	AO	Voltage feedback output 0–10VDC
17	DGND	Supp	(connected to pin 7) Common ground to pins 8–9, 18–20, 24, 25
18	APP_DIGIO_1	DI/O	Digital input/ouput[3] 0-2VDC/10–28VDC
19	APP_DIGIO_2	DI/O	Digital input/ouput[3] 0-2VDC/10–28VDC
20	APP_DIGIO_3	DI/O	Digital input/ouput[3] 0-2VDC/10–28VDC No default function
21	REL3_14	RO	Relay output 3 normally open (warning)
22	REL3_12	RO	Relay output 3 normally closed (warning)
23	REL3_11	RO	Relay output 3 common (warning)
24	APP_DIGIO_5	DI/O	Digital input/ouput[3] 0-2VDC/10–28VDC No default function
25	+24 VDC	Supp	+24VDC I/O Aux power output 24VDC, max. 650mA

[1] Pin 5 (0 VDC) is used as the reference earth for pin 25 (24 VDC) and is connected internally to the equipotential bonding via a 1 kΩ resistor to earth.
[2] Maximum switching current: 1 A; maximum switching voltage: 24 V. [3] On request digital pins can be programmed for a specific application.

DIGITAL I/O	
Number of Digital Inputs/Outputs	6 (each can be used as input or output)
Output Voltage Supplied for Digital I/O	24VDC (-15%/+20%)
Digital Input Characteristic	IEC61131-2 Type 1
Digital Input Filter	3.2ms (10µs, 1ms and 10ms factory configurable)
Digital Output Switching Time	T_{ON}: 64-120µs, T_{OFF}: 90-170µs
Update Rate Digital Outputs	1kS/s

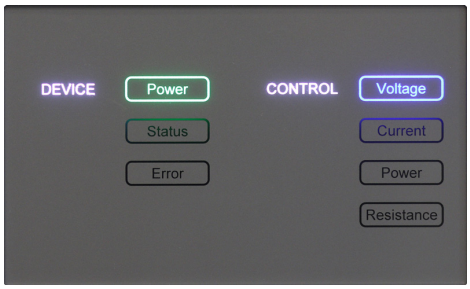
DIGITAL I/O	
Max Voltage Digital Inputs	30VDC
Sampling Rate Digital Inputs	1kS/s
Digital Output Type	High-side switch
Load Type	Ohmic, inductive, lamp load
Max Total Output Current (All Channels)	0.65A
Max Output Current Per Channel	0.625A (short circuit proof)

RELAY OUTPUTS	
Number of Relay Outputs	2 × SPST (NO), 1 × SPDT
Load Type	Ohmic, inductive, lamp load
Max Switching Voltage	30VDC
Max Switching Current	SPST: 3A, SPDT: 1A
Update Rate	48kHz

HIGHLIGHTED FEATURE

FRONT PANEL INDICATION

As standard the front panel has backlit indicators which illuminate to show which control mode the power system is operating in (CV, CC, CP, CR). When the G5-BATSIM has been successfully energised, the corresponding power light illuminates green to indicate this. An illumination is also provided to visually warn users of any status (yellow) or error (red) message.



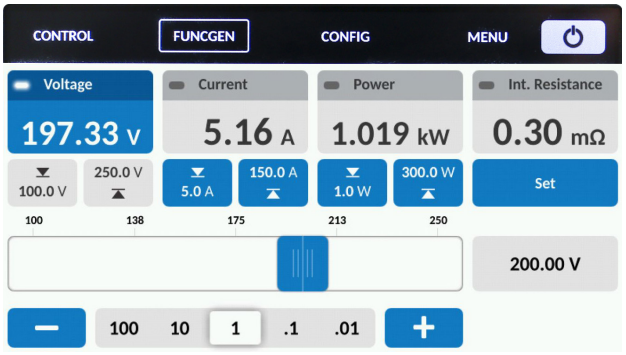
OPTIONAL INTERFACES

CODE	DESCRIPTION
/HMI	Lockable touchscreen HMI providing front panel control and measurement
/CANMP	Multi-protocol CAN interface with up to 100 user configurable messages

HIGHLIGHTED OPTIONS

TOUCHSCREEN HMI (/HMI)

The optional HMI provides a simple and intuitive way of control and measurement via a touchscreen panel. Users can directly access features such as the system's protections, warnings/errors and optional function generator without the use of a computer. A user defined passcode can be set to lock the touch screen, which prevents unauthorised access. When selected, the HMI replaces the front panel indicator.



CAN MULTI-PURPOSE INTERFACE (/CANMP)

CANmp is a high speed digital interface operating at 1kHz. The interface gives users the capability to customise the CAN protocol. Up to 100 messages are user configurable. Along with the CAN ID the data length code, byte order, start bit, data type and signal factor can be adjusted by the user. A DBC file is provided and messages can be easily configured within the standard windows software. Messages can be sent cyclically or upon receipt of a sync or syncID signal.

SOFTWARE/SOFT TOOLS

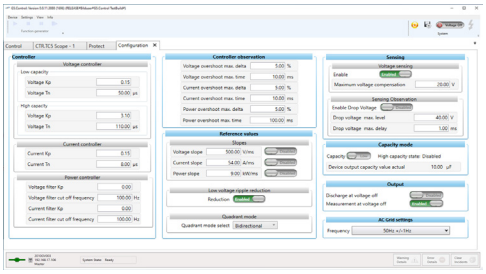
STANDARD G5.CONTROL GUI

All G5-BATSIM units come with a simple and intuitive G5.Control operating GUI as standard. Live values of the battery simulator are displayed graphically along with any warning and error messages. The software provides a variety of second level parameters, ideal for users who like to optimise their test processes. In standard user mode the operator can remotely program set values, enable voltage output as well as the ability to analyse different variables including set and actual values via the integrated scope.

The scope function can simultaneously record up to 8 system variables. Recording can be started manually or by a defined trigger event from any variable of the system. All actual and set values (currents/voltages/power/internal resistance) can be recorded. Other recordable items include system temperatures, intermediate DC circuit, low voltage auxiliary power supplies, error related values and variables from the controller section.

A password protected section is available to the advanced user and service technician. In addition to the standard functions the authorised user is able to:

- Program linear ramp functions at start up and set value steps during operation
- Configure multi-unit operation
- Program the PID controller parameters
- Program the unit's limit values
- Calibrate and adjust values as necessary
- Update the firmware



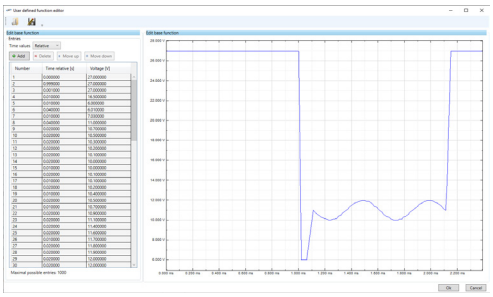
OPTIONAL SOFTWARE

CODE	DESCRIPTION
/TFE	Integrated function generating engine for time based programming, including sweep function
/APP	Integrated function generating engine with application area (parametric) programming
/BATSIM	GUI simulating battery characteristics with adjustable parameters (option for slave modules only, installed as standard to master module)
/BATCONTROL	Energy storage and drive cycling GUI
/SASCONTROL	Solar array simulation GUI (includes AAP option)

HIGHLIGHTED OPTIONS

FUNCTION GENERATOR (/TFE & /APP)

Complex DC waveforms can be implemented through an optional embedded function generator. The highly programmable nature of the function generator allows users to plot out exact waveforms. This is often advantageous when emulating a power device with a very specific behaviour profile. For example, when quality testing fuel cell powered equipment, the specific behaviour of a discharging fuel cell can be programmed and replicated.



As well as custom shapes, standard square, sawtooth and sine waveforms can be plotted against time. Voltage/current and voltage/power relationships can also be programmed where necessary. Parametric programming is possible when selecting option /APP, where instead of the time axis, an input variable (V_{IN}, I_{IN} or P_{IN}) can be selected.

APPLICATION SPECIFIC GUIs

HIGHLIGHTED SOFTWARE

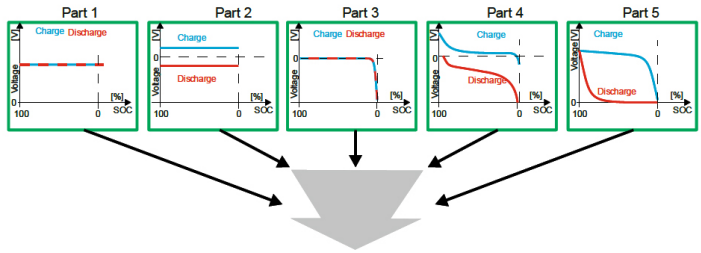
STANDARD BATTERY EMULATION GUI

Advanced BatSim software is installed on the master module of each system as standard, and is optionally available for slave modules. The GUI allows users to emulate different sized battery packs. Nearly all relevant electrical characteristics are programmable including: the number of cells in series/parallel, state of charge, energy capacity, cut off limits, chemistry type and nominal voltage.

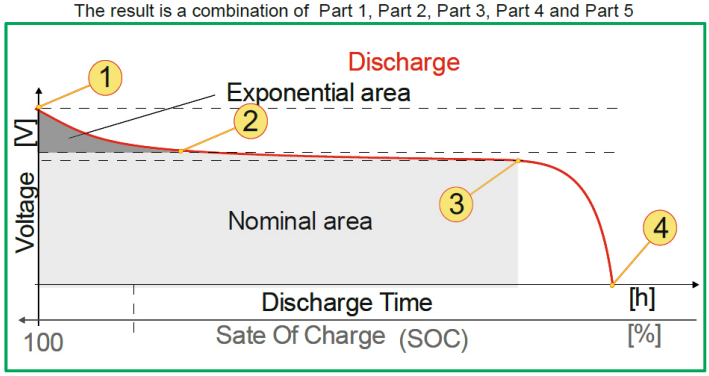
The multi-channel data logger provides live reporting and output to file (CSV) with timestamps. Previously recorded data can be imported, reviewed and compared in the analyser mode. Hard to replicate conditions, such as a cranking curve from a cold start can be programmed and repeated when used in conjunction with the function generator.

BastSim is based on the comprehensive Tremblay Dessaint model. The model is built from the charge/discharge curves in the example above right. The example shows:

- Part 1: Nominal voltage
- Part 2: Internal resistance loss
- Part 3: Polarisation voltage
- Part 4: Polarisation resistance
- Part 5: Exponential zone voltage



The result is a combination of Part 1, Part 2, Part 3, Part 4 and Part 5



To emulate your specific battery pack accurately, the following information from the battery's datasheet can be inputted. This corresponds to the graph below right:

- 1: Fully charged battery
- 2: Start of exponential the zone
- 3: End of the nominal and start of the exponential zone
- 4: End of discharging/start of charging

ISOLATION

STANDARD FEATURES

TECHINCAL DATA	
DC+/DC- Output to PE	1500VDC
Input Isolation Test Voltage (Line to Case/Logic)	2500VDC (1s)
Output Isolation Test Voltage (Output to Case/Logic)	3330VDC (1s)
AC Terminals to PE	900VDC
AC to DC Terminals	1500VDC
Resistance (DC+/DC- output to PE)	X713 jumper inserted: 22MΩ, X713 jumper removed: open

MECHANICAL

STANDARD FEATURES

TECHINCAL DATA	
AC Terminals	Screw terminals for 6 to 25 mm^2 (18kW models)/ 6 to 35 mm^2 (27-54kW models) wires, diameter ≤8.5mm
DC Terminals	Output bars for M8 bolts
Cooling	Direct forced air, front to back
Operating Altitude	≤2000m above sea level (slight temperature derating possible above 1000m)
Operation Temperature	-5°C to +50°C when continuous I_{IN} is <68ARMS, -5°C to +40°C when continuous I_{IN} is >68ARMS (-5°C to +40°C when optional air filter is installed at any input current)
Storage Temperature	-25°C to +70°C
Relative Humidity	0 to 95% (non condensing)
Vibration	IEC 60068-2-6 (Test Fc)
Acoustic Noise Level (1m From Front of Unit)	<54dB (90% P_{MAX}/90% I_{MAX} at +25°C ambient)

SAFETY AND PROTECTION

STANDARD FEATURES

TECHNICAL DATA	
Over Voltage Protection	Programmable
Over Current Protection	Programmable
Over Power Protection	Programmable
Over Temperature Protection	Standard
Protection Class	1 (EN 62477-1)
Degree of Pollution	2 (EN 60664-1)
Overvoltage Category	Mains input, EN 60664-1: 3, other interfaces: 2
Safety of Machinery	EN ISO 13849-1:2015 N/A (without option /ISR), PL c (with 2 channel /ISR), PL e (with 2 channel /ISR and external safety relay)
Safety Requirements for Power Electronic Converter Systems and Equipment	EN 62477-1:2017, Low Voltage Directive 2014/35/EU
Emission Standards for Industrial Environments	EN 61000-6-4:2007+A1:2011
Immunity Standards for Industrial Environments	EN 61000-6-2:2005
Electrical Equipment for Measurement, Control and Laboratory Use	EN 61326-1:2013 (industrial level A)
Restriction of Hazardous Substances	EN IEC 63000:2018

OPTIONS

CODE	DESCRIPTION
/ISR	Integrated Safety Relay, e-stop interface for shutdown to EN ISO 13849-1:2015, Performance Level c
/PACOB	Protection against accidental contact of the AC terminal block
/RPP	Automatic voltage matching with reverse polarity protection
/XCD	AC safety discharge circuit discharging AC lines to <60V in <1s of AC power loss, required to meet EN 62477-1 for AC plug connections

HIGHLIGHTED OPTIONS

AUTOMATIC VOLTAGE MATCHING WITH RPP (/RPP)

For users who also need to test energy storage devices, Reverse Polarity Protection (RPP) is recommended for devices without an automatic voltage matching circuit. With the G5-BATSIM energised but output off, the RPP senses the voltage of the connected energy storage device. A contactor is closed after matching the voltage, to prevent large inrush currents and arcing on start up. The sense lines of the G5-BATSIM are used to measure the battery voltage. A switched sense is also provided ensuring there is quiescent current draw at voltage off state.

INTEGRATED SAFETY RELAY (/ISR)

For additional safety, a mechanical interlock is available for the mains input of the G5-BATSIM. The integrated safety relay provides shutdown safety according to EN 13849-1 category 2/3. The ISR is connected to the external safety switch loop. If the external loop is opened, the DC-output of the power system is powered down immediately.

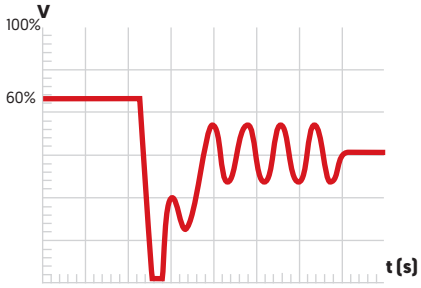
PROTECTION AGAINST CONTACT (/PACOB)

A specially produced cover is optionally available which provides protection against accidental contact of AC terminal block (rated to IP20). A cover for the DC output bars in provided as standard.

COMMON G5-BATSIM APPLICATIONS

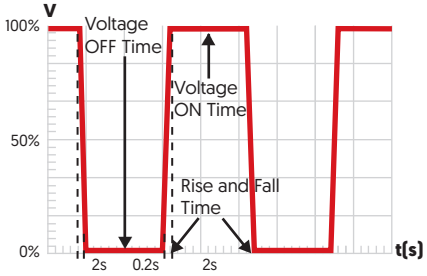
CRANKING CURVE TESTING

Electrical components within a vehicle's subsystem must be able to withstand a wide range of input voltage surges and drops during a start-up. The G5-BATSIM can accurately recreate these conditions within a lab environment. This increases reproducibility and accuracy of results when compared to using real batteries. Hard to replicate conditions such as voltage cranking during a cold start can be achieved. Voltage/current and voltage/power relationships can be programmed against time where necessary.



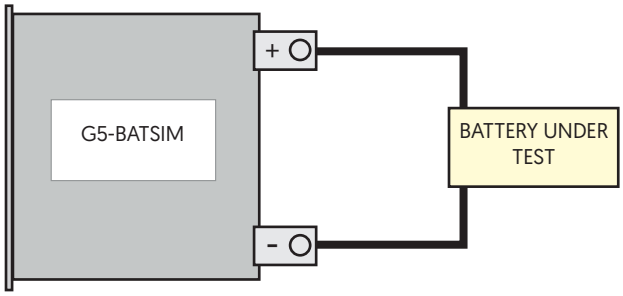
PULSED BATTERY CHARGING

Pulse charging interrupts the traditional DC charging curve with short relaxation periods. The technique is thought to improve battery discharge capacity and help facilitate longer cycle life. Some studies have shown that pulse charging is also helpful in eliminating concentration polarisation. The G5-BATSIM's embedded function generator allows the PSU to deliver short burst of highly concentrated energy at user defined time intervals. The technique can also be used for powering lasers, electromagnets and plasma generation.



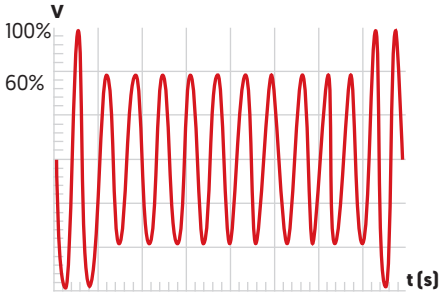
AC RIPPLE ON BATTERY LINK

A potential side effect of charger circuits that contain both AC and DC components is electrical noise. The ripple causes unwanted fluctuations in battery temperature, which results in deterioration of the battery's performance. By utilising the G5-BATSIM's optional embedded function generator the user can set a current ripple at up to 10kHz to simulate this phenomenon.



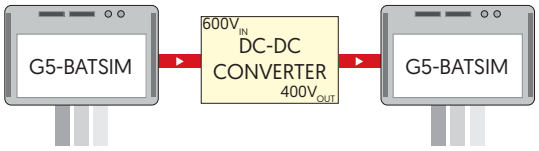
VOLTAGE DROPS & INTERRUPTS

In electronic systems sudden voltage interruptions may cause unexpected behaviour. Supply line disturbances may have several causes, including an additional switch on of large capacitive loads parallel to the supply line or a short circuit caused by loads sharing the supply. The G5-BATSIM can generate many complex DC waveforms to test devices under realistic conditions to identify any potential issues.



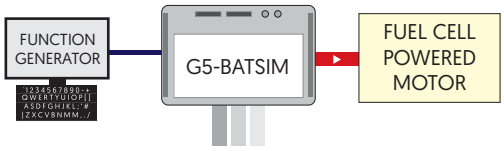
INVERTER/CONVERTER TESTING

The DC input of virtually any power conversion device can be replicated. The influence that variables, such as line voltage variation, have on performance can be isolated and tested. This allows optimum operating conditions to be characterised to improve efficiency and performance.



FUEL CELL EMULATION

The discharge behaviour of an FCEV's fuel cell is often irregular. By using the function generator, both conservative and aggressive driver profiles can be replicated. This allows the G5-BATSIM to perform effective quality testing of fuel cell powered components under all likely operating conditions.



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