DC-DC Converter Module User Manual

2G Engineering

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Revision History

REV	DATE	Editor	DESCRIPTION
-	1-16-2024	JL	Initial Release

Overview

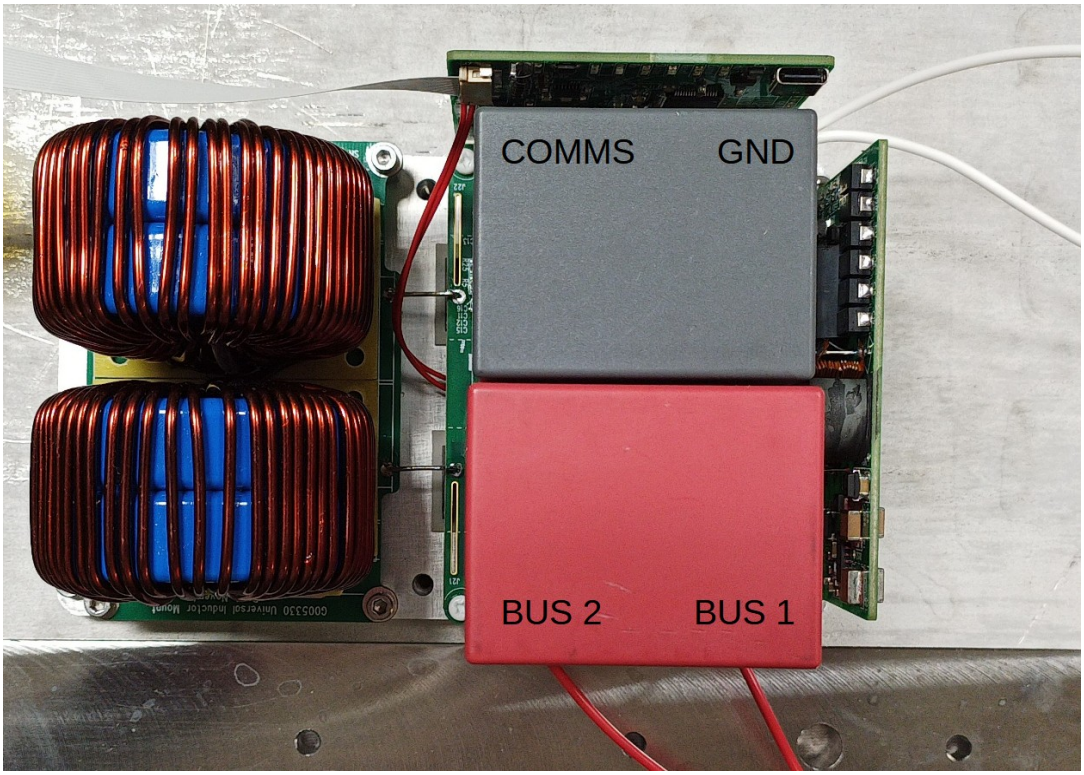
The 2G Engineering DC/DC converter module is a versatile PBOF-capable subsea power supply module.

Features

- PBOF-capable for subsea applications
- Dual-bus design
- Bi-directional buck-boost topology. Can move power from bus 1 to bus 2 or bus 2 to bus 1, regardless of the relative voltage between the two busses.
- Standard configurations available for up to 1000V DC operation on each bus (higher voltage configurations may be available upon request)
- Supports both voltage and current regulation
- Provides feedback on voltage, current, power, and temperature

Layout

The module can be provided in various physical configurations depending on customer requirements. A common configuration is shown below as an example.



Connections

DC Bus

The power supply module requires, at a minimum, a connection to each of the two power busses and ground for operation. The exact configuration of the power bus wiring, including connectors, wire length, etc. may vary depending on customer requirements. If the module is ordered in a configuration where the two busses have asymmetrical voltage limits, bus 1 will always be the higher of the two.

Communications

A communications connection may be optional depending on the configured operating mode of the module. Communications is provided using a 1mm pitch, 12-pin flat flex cable. The contacts of the flex cable should face upward when installing it. A flex cable with a dielectric strength rating appropriate to the operating voltage of the system is recommended. The pinout of the communications connector is provided below:

Pin	**Function**
1 (top of board)	RS-422 RX+ (in to module)
2	RS-422 RX- (in to module)
3	RS-422 TX- (out from module)
4	RS-422 TX+ (out from module)
5	Status out (RS-232 level)
6	Reset in (RS-232 level)
7	N/C
8	+18V
9	+12V
10	+5V
11	+3.3V
12	GND (see note below)

Note: GND pin on communications connector should typically be unused, and communications ground should instead be tapped off of power ground to avoid formation of dangerous ground loops. If the communications interface is fully isolated, it may be possible to safely use the ground on the communications connector. It is the responsibility of the system integrator to select a safe grounding topology.

2G Engineering can provide a compatible USB to RS-422 adapter with galvanic isolation for test and development purposes upon request. 2G Engineering also offers the G005251 “Conductor” board, which provides integration of up to 6 power supply modules, along with protocol bridging to RS-232, RS-485, CAN bus, and Ethernet.

Logic Power

The standard configuration of the power supply module includes an onboard “house” power supply which provides the required regulated low voltage busses required by the module for its own operation. Power will be drawn from either bus 1 or bus 2, depending on which has the higher voltage. These low voltage busses are also available on the communications connector, and can potentially be used to power other system loads. Contact 2G Engineering for more information if you wish to use the low-voltage busses in your application.

The power supply module can also be configured to derive its logic power from an external 24-48V bus, independent of the two power busses. Contact 2G Engineering for more information on this configuration.

Operation

Regulation

The power supply implements cascaded control loops to provide both voltage and current regulation. The supply can be configured to regulate the voltage on bus 1 or bus 2, and the power supply module will attempt to hold that voltage by calculating a current reference. The current reference will be a positive value if the supply wants to move energy from bus 1 to bus 2, or a negative number if the supply wants to move energy from bus 2 to bus 1. The current reference value is subject to minimum and maximum constraints. By default, these are symmetrical to allow current to flow in both directions, but they can be changed to asymmetrical values if unidirectional operation is required.

If the supply is unable to reach the programmed voltage setpoint, the current reference will saturate at the programmed minimum or maximum current limit value. This means the supply will effectively operate in a constant-current/constant-voltage (CC/CV) mode, which is suitable for battery charging, among other applications.

The supply can also be operated in current mode directly, with voltage regulation taken out of the loop. This may be useful for some applications. Note that a load is required in this operating mode to constrain the bus voltage, otherwise it will rise in an uncontrolled manner and the supply will shut down due to overvoltage.

Finally, the supply can be operated in a duty-cycle mode. This enforces a strict ratiometric relationship between the voltages on the two power busses, which may be useful in certain applications.

Startup

By default, the module will start up in the off state. It can be configured with a default mode and control setpoint which will be applied on startup after a configurable delay. If any control settings are changed before the startup delay expires, or if any faults are detected, the automatic startup will be canceled.

Safety

The power supply module is constantly monitoring the voltage on both power busses along with current and temperature. The module is also equipped with transient voltage suppressors (TVS) on both power busses, and monitors the current through these devices as well. The supply will shut down if safety limits on any of these parameters are exceeded. Safety limits for each parameter have been preset at the factory to values that will prevent damage to the system. 2G Engineering strongly recommends that customers do not increase these limits above the default values in order to prevent damage to the power supply module, which would not be covered under warranty. Safety limits may be *decreased* as needed by customers to protect connected equipment.

An undervoltage lockout (UVLO) is also implemented which will pause operation of the supply if voltage on either bus is below its respective limit value. This can be useful when powering a constant-current or constant-power load through a high-impedance connection, which could otherwise result in a dangerous current runaway scenario under certain operating conditions.

Usage

As the power supply module is intended for integration into a larger system, the exact usage details will vary from customer to customer. An example usage scenario is presented below:

1. Apply power to one or both DC busses. Power LEDs on the module should illuminate.
2. Establish serial communications with the module.
3. Verify the VBUS1_MEAS and VBUS2_MEAS registers report the expected voltages for their respective busses.
4. Set the desired operating voltage. To set bus 2 to 350V, write 350 to VBUS2_SETPOINT.
5. Set the regulation reference source. Write 2 to REF_SRC to begin regulating bus 2 to the specified voltage.
6. Read the VBUS1_MEAS, VBUS2_MEAS, I_IND_MEAS, PWR_EST, TEMP1, TEMP2, and SYSTEM_FAULTS registers to monitor system status.
7. Setpoint and reference source registers can be modified as needed while the system is in operation.
8. Write 0 to REF_SRC to turn the supply off.

Interface

The power supply module provides an RS-422 interface for communications. By default, it operates at 115200 baud, 8N1, but can be reconfigured as required for specific applications. The module uses the standard Modbus RTU protocol with a default device address of 1. 2G Engineering's free JAMBUI software can be used for communication with the device during development and testing.

Registers

Modbus registers in 2G devices are referred to here by name. Please see the register map file for this product for the mapping between register names and Modbus register addresses, as well as data formats and units. Further documentation on the 2G register map format is available in the help file in the JAMBUI application.

System

COUNT

Increments by 1 after each read. Useful to verify that you are getting fresh data.

ERR

Mirrors the first 16 bits of the SYSTEM_FAULTS register, see that register for bit descriptions.

REGMAP

Read this register repeatedly to download the Modbus register map from the device in CSV format.

END1, END2, END4

Endian test useful for verifying Modbus implementation, returns/expects 0x0201, 0x04030201, 0x0807060504030201, respectively.

FLOAT32, FLOAT64

Endian test useful for verifying Modbus implementation, returns/expects 3.141592653589793 in 32/64-bit floating point format, respectively.

FACT

Factory test register, not for customer use.

UUID

Register map UUID. Uniquely identifies the register map in the device. Can be useful for caching register map and checking for map changes between firmware versions.

VERS_MAJOR

Firmware major version (e.g. *.0).

VERS_MINOR

Firmware minor version (e.g. 3.*).

BUILD_NUM

Firmware build number. Each version of firmware has a unique build number which can be used to identify it for support purposes.

BUILD_DATE

Date and time on which the firmware was compiled (YYYY-mm-dd HH:MM:SS).

SERIAL_NUM

96-bit hardware serial number, unique per module.

UPTIME

The amount of time the module has been powered on (rolls over every 49.7 days).

ISP_MODE

Write 1 to enter serial or USB programming mode.

SYS_RESET

Write 1 to reboot the module. Module must be in the OFF state before rebooting.

WRITE_CONFIG

Write 1 to copy configuration registers to EEPROM. If settings are not written to EEPROM, they will be lost the next time the module is rebooted or power cycled.

LOAD_DEFAULTS

Write 1 to load default settings. This should be followed by a WRITE_CONFIG to save the new settings, otherwise the system will revert to the previously-saved values on the next reboot.

SYSTEM_FAULTS

Indicates fault conditions that the system has detected. Fault conditions are indicated by a 1 in the corresponding bit position. Faults can be cleared by writing a value to this register with the corresponding bits set. Faults are defined as follows:

Fault Number	**Description**
0	Bus 1 over voltage
1	Bus 2 over voltage
2	Inductor over current
3	Bus 1 over current
4	Bus 2 over current
5	Module over temperature
6	Module under temperature
7	Bus 1 TVS activated
8	Bus 2 TVS activated
9	Internal firmware logic fault

10	Internal file system error
11	Communications with host timed out
12	Invalid parameter provided via Modbus
13	Configuration read error
14	Configuration write error
15	Power-on reset. Set every time the unit powers on. Useful to detect power cycles.
16-31	Reserved

LAST

Indicates the end of the register map. Always returns 0x6789ABCD.

Configuration

All configuration registers will be reset to previous values on the next reboot or power cycle unless saved to persistent storage using the WRITE_CONFIG register.

SERIAL_BAUD

Sets the baud rate for the RS-422 serial interface. Takes effect immediately. 115200 is the only supported baud rate on the current firmware version.

USER_SN

User-definable serial number. Does not affect module operation.

MODBUS_ADDR

Sets the Modbus device address for the RS-422 serial interface. Takes effect immediately. 1 is the only supported address on the current firmware version.

MODBUS_MODE

Sets the Modbus protocol mode on the RS-422 serial interface. (0 = RTU, 1 = ASCII). RTU is the only supported protocol mode on the current firmware version.

MODBUS_ZERODELAY

The Modbus RTU protocol requires a short delay between packets. However, this delay is not required in many Modbus implementations, and eliminating it can substantially increase communications throughput. If this register is set to 1, the delay will be disabled.

HOST_COM_TIMEOUT

Sets the amount of time the module can go without receiving any Modbus messages before a loss of communications is flagged.

COM_TIMEOUT_ACTION

Action to take if communications are lost.

0 = Report fault and continue operation

1 = Set supply to the OFF state

TS_ENABLE_BITS

Temperature sensor enable bits. A bit set in this register indicates that the corresponding temperature sensor is enabled. Should be pre-configured from the factory to match the temperature sensors supplied with the module.

TEMP_MIN

Minimum allowable operating temperature.

TEMP_MAX

Maximum allowable operating temperature.

DEFAULT_V1_SP

Default bus 1 voltage setpoint. The bus 1 setpoint is set to this value when the module is powered on.

DEFAULT_V2_SP

Default bus 2 voltage setpoint. The bus 2 setpoint is set to this value when the module is powered on.

DEFAULT_I_SP

Default inductor current setpoint. The inductor current setpoint is set to this value when the module is powered on.

DEFAULT_PWM_DC

Default PWM duty cycle setting. The PWM duty cycle is set to this value when the module is powered on.

DEFAULT_PWM_MODE

Default PWM mode setting. The PWM mode is set to this value when the module is powered on. (See PWM_MODE_SEL for allowed values.)

DEFAULT_REF_SRC

Default control reference source. The control reference source is set to this value when the module is powered on. (See REF_SRC for allowed values.)

STARTUP_DELAY

Sets the amount of time the module will wait before applying the default settings on startup. If any control settings are changed during this interval, the default settings will not be applied.

V1_SP_MIN

Sets the minimum voltage setpoint that can be commanded for bus 1.

V1_SP_MAX

Sets the maximum voltage setpoint that can be commanded for bus 1.

V2_SP_MIN

Sets the minimum voltage setpoint that can be commanded for bus 2.

V2_SP_MAX

Sets the maximum voltage setpoint that can be commanded for bus 2.

I_IND_SP_MIN

Sets the minimum inductor current that can be commanded.

I_IND_SP_MAX

Sets the maximum inductor current that can be commanded.

V1_FAULT_LIMIT

Sets the fault voltage for bus 1. A fault will be tripped and the supply will shut down if the voltage on bus 1 exceeds this value.

V2_FAULT_LIMIT

Sets the fault voltage for bus 2. A fault will be tripped and the supply will shut down if the voltage on bus 2 exceeds this value.

I_IND_FAULT_LIMIT_MIN

Sets the lower fault current for inductor current. A fault will be tripped and the supply will shut down if the measured inductor current exceeds this value in the negative direction.

I_IND_FAULT_LIMIT_MAX

Sets the upper fault current for inductor current. A fault will be tripped and the supply will shut down if the measured inductor current exceeds this value in the positive direction.

V1_N_FAULT_LIMIT

Sets the number of consecutive samples with bus 1 voltage in excess of the fault limit that must be seen before the fault is actually triggered.

V2_N_FAULT_LIMIT

Sets the number of consecutive samples with bus 2 voltage in excess of the fault limit that must be seen before the fault is actually triggered.

I_IND_N_FAULT_LIMIT

Sets the number of consecutive samples with inductor current in excess of one of the fault limits that must be seen before the fault is actually triggered.

V1_TVS_LIMIT

Sets the number of consecutive samples with bus 1 TVS activated that must be seen before the fault is actually triggered.

V2_TVS_LIMIT

Sets the number of consecutive samples with bus 2 TVS activated that must be seen before the fault is actually triggered.

FAULT_RETRY_INT

Interval between retries after fault. Not supported in current firmware version.

FAULT_RETRY_COUNT

Number of retries after fault before giving up. 0 specifies that retries should continue indefinitely. Not supported in current firmware version.

MODE_THR_1, MODE_THR_2, MODE_THR_3, MODE_THR_4

Configures V1/V2 ratio for automatic transitions between PWM modes. Pre-configured from factory; should not need to be changed by customers.

V1_PID_*

These registers configure control loop gains when regulating bus 1 voltage. They have been pre-tuned at the factory and should not need to be adjusted by customers.

V1_PID_OUT_MIN

Configures the minimum current limit when regulating bus 1 voltage.

V1_PID_OUT_MAX

Configures the maximum current limit when regulating bus 1 voltage.

V2_PID_*

These registers configure control loop gains when regulating bus 2 voltage. They have been pre-tuned at the factory and should not need to be adjusted by customers.

V2_PID_OUT_MIN

Configures the minimum current limit when regulating bus 2 voltage.

V2_PID_OUT_MAX

Configures the maximum current limit when regulating bus 2 voltage.

I_IND_PID_*

These registers configure control loop gains when regulating inductor current. They have been pre-tuned at the factory and should not need to be adjusted by customers.

V1_UVLO_LO

Configures the undervoltage lockout level for bus 1. When the voltage on bus 1 falls below this value, power supply operation will be paused.

V1_UVLO_HI

Configures the undervoltage lockout level for bus 1. When the voltage on bus 1 rises above this value, power supply operation will be resumed, assuming the voltage on bus 2 is also above its UVLO limit.

V2_UVLO_LO

Configures the undervoltage lockout level for bus 2. When the voltage on bus 2 falls below this value, power supply operation will be paused.

V2_UVLO_HI

Configures the undervoltage lockout level for bus 2. When the voltage on bus 2 rises above this value, power supply operation will be resumed, assuming the voltage on bus 1 is also above its UVLO limit.

ALLOWED_REF_SRC

Sets the enabled reference sources. A 1 in bit position *n* means that *n* is a valid value for REF_SRC. (Bit 0 is always forced to 1).

*_ALG_SCALE, *_ALG_OFFSET

These registers are used at the factory for hardware configuration and should not be modified by customers.

Feedback

VBUS1_MEAS

Reports measured voltage on bus 1.

VBUS2_MEAS

Reports measured voltage on bus 2.

I_IND_MEAS

Reports measured current in inductor.

PWR_EST

Reports the estimated power output of the module.

V3P3_MEAS

Reports the measured voltage on the internal 3.3V bus.

V18_MEAS

Reports the measured voltage on the internal 18V bus.

TEMP_CPU

Reports the measured temperature of the module's CPU.

TEMP1

Reports the measured temperature on sensor 1. If sensor 1 is not installed, this register will report NaN.

TEMP2

Reports the measured temperature on sensor 2. If sensor 2 is not installed, this register will report NaN.

TVS_BLEED

Reports the activation state of the Transient Voltage Suppressors. Bit 0 set indicates that the TVS on bus 1 is activated, and bit 1 set indicates that the TVS on bus 2 is activated. This indicates that the corresponding bus is over its recommended operating voltage. Long-term operation in this state may result in hardware damage.

Control

REF_SRC

Enables operation of the supply and sets the source that the supply should use for reference when regulating.

0 = Output off

1 = Regulate bus 1

2 = Regulate bus 2

3 = Regulate inductor current

4 = Operate in fixed duty cycle mode

VBUS1_SETPOINT

Configures the setpoint for bus 1 voltage. Only used if REF_SRC is set to 1.

VBUS2_SETPOINT

Configures the setpoint for bus 2 voltage. Only used if REF_SRC is set to 2.

I_IND_SETPOINT

Configures the setpoint for inductor current. Only used if REF_SRC is set to 3.

PWM_DC

Configures the duty cycle setpoint (0-100%). Only used if REF_SRC is set to 4.

PWM_MODE_SEL

Configures the PWM mode when in fixed duty cycle mode. Only used if REF_SRC is set to 4.

0 = off

2 = Bus 1 > Bus 2

3 = Bus 1 approximately equal to V2

4 = Bus 1 < Bus 2

AB_DUTY, CD_DUTY

Reports internal PWM duty cycle.

I_REF

Reports the current reference that the module is currently attempting to track.

ACTIVE_MODE

Reports the PWM mode selected by automatic control when REF_SRC is set to 1, 2, or 3.

0 = off

1 = operation paused due to UVLO

2 = Bus 1 > Bus 2

3 = Bus 1 approximately equal to V2

4 = Bus 1 < Bus 2

SAMPLE_PT

Used for development and test purposes by the factory, should not be changed by customers.