QCIOT-ELOADPOCZ

The QCIOT-ELOADPOCZ load board is a programmable electronic load for the Quick-Connect ecosystem that enables system stress testing while prototyping.

Included is the SLG4BE46142V programmable mixed-signal IC that serves as an I^2C-enabled controller for selecting current load.

The board provides a standard Pmod™ Type 6A (extended I^2C) connection for the on-board sensor to plug into any required MCU evaluation kit with a matching connector. The QCIOT-ELOADPOCZ features Pmod connectors on both sides of the board to allow additional Type 6/6A boards to connect in a daisy-chained solution with multiple devices on the same MCU Pmod connector.

The software support that is included with the Renesas IDE (e^2 studio) provides code generation to connect the device and the MCU so that development time is significantly reduced. With its standard connector and software support, the QCIOT-ELOADPOCZ is ideal for the Renesas Quick-Connect IoT to rapidly create an IoT system.

Features

- Max 2.5A of load current or 4W
- Wide input voltage range (0.8V to 10V)
- Programmable load timing through I^2C
- Standardized type 6A Pmod connector supports I^2C extended interface
- Dual connectors allow pass-through signals for daisy-chained solutions
- Software support in e^2 studio minimizes development time with one-click code generation

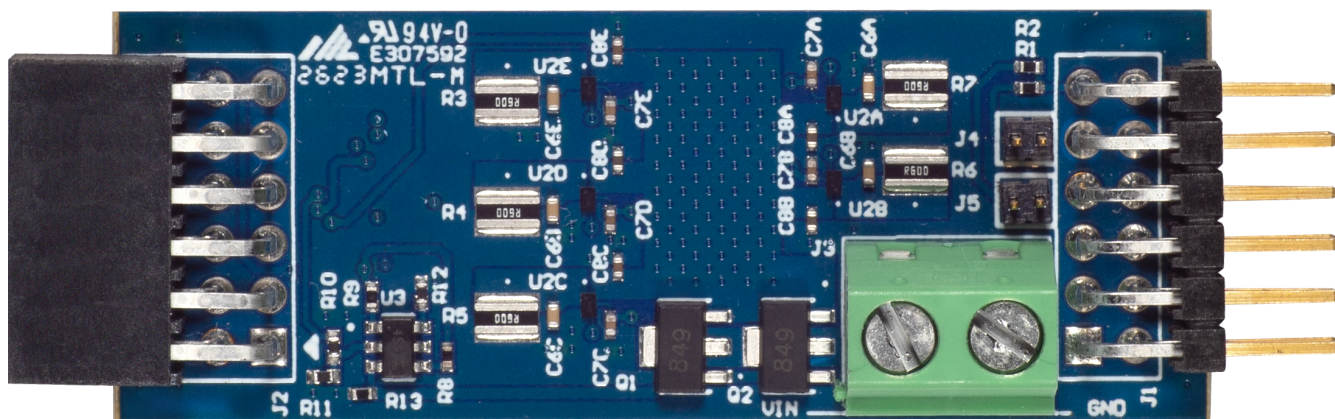## Board Contents

- QCIOT-ELOADPOCZ board

Figure 1. QCIOT-ELOADPOCZ Image

Contents

1. Functional Description

The QCIOT-ELOADPOCZ is intended as a quick connect prototyping solution for programmable loading. The board enables the designer to quickly test and characterize a variety of applications that can include driver circuits, batteries, and power supplies. The QCIOT-ELOADPOCZ takes external voltages between 0.8V to 10V and can draw up to a maximum of 4 watts.

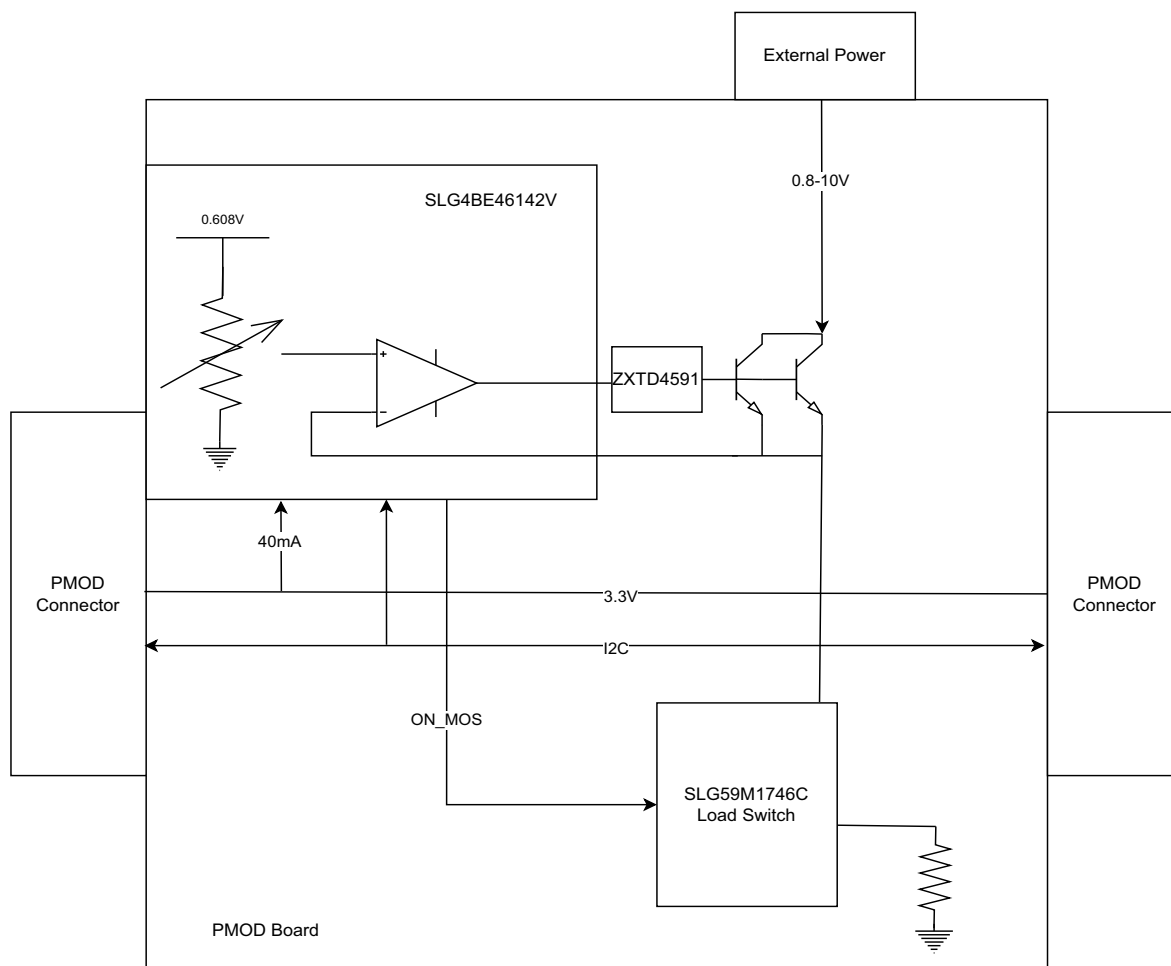The block diagram highlights the main parts of the system:

Figure 2. QCIOT-ELOADPOCZ Block Diagram

The building blocks of the QCIOT-ELOADPOCZ and their functionality are as listed:

SLG4BE46142V – Programmable mixed-signal IC with operational amplifiers, digital rheostats, EEPROM, and a wide set of analog and digital macrocells. Current load is set using the digital rheostats on the SLG4BE46142V that uses an on-chip voltage reference and operational amplifier to set the voltage across multiple legs of load resistors on the board. These legs are also enabled using the SLG4BE46142V.

SLG59M1746C – Ultra-low Power, rds(on) 17.6mπ, 1A, 0.82 mm2 WLCSP load switch with controlled inrush current. Five on-board load switches can be enabled or disabled to control five legs of current across load resistors, which total up to 5A. Each leg has a maximum current of 1A that is set by the reference voltage and digital rheostats of the SLG4BE46142V.

1.1 Operational Characteristics

The QCIOT-ELOADPOCZ has been designed to the following specifications:

▪ Input voltage range: 0.8V–10V

▪ Output current range: 0A–2.5A (limited to 4W)

▪ Maximum ON time of 100ms with 2.5A output at 3.3V input

Operational ON time of the QCIOT-ELOADPOCZ is limited by the safe operating range of the ZXTN2007ZTA BJT. The collector current and collector-emitter voltage are the determining factors for ON time within safety range.

The board input voltage is the collector voltage of the BJT, while the emitter voltage is set by the SLG4BE46142V op amp reference voltage (maximum 0.608V). Therefore, the minimum input voltage is roughly 0.8V (max reference voltage plus 200mV buffer for saturation VCE). The maximum input voltage depends upon the ON time required for current, within the safety range:
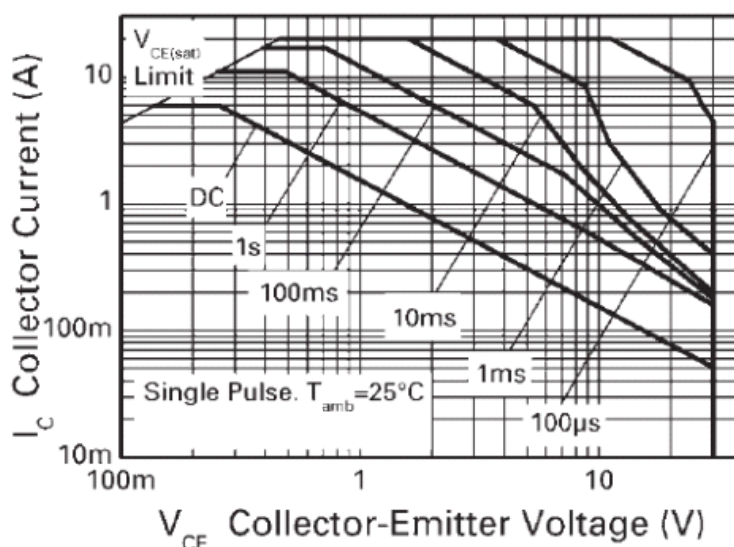

Figure 3. Safe Operating Range

If operating at high currents, QCIOT-ELOADPOCZ board users should consider the amount of time the module is ON for their application and pre-program turning ON and OFF the module output accordingly. *Caution*: Exceeding the safety range might result in failure of operation and/or physical harm from overheating the board.

1.2 Setup and Configuration

The following additional lab equipment is required for using the board (and is sold separately):

▪ FPB-RA4E1

1.2.1 Software Installation and Usage

Visit the Renesas website for the latest version of the e^2 studio installer. Renesas recommends version 2024 or later. The minimum FSP version supporting the QCIOT-ELOADPOCZ is FSP 5.1.0. For the latest sensor support, ensure that the latest release is used.

Visit the Renesas Quick-Connect IoT site for more information about creating your customized system solution.

1.2.2 Kit Hardware Connections

Follow these procedures to set up the kit (see Figure 4).

1. Ensure that the MCU evaluation kit in use has a Pmod connector set to Type 6A (refer to the kit hardware manual for details). Renesas recommends using FPB-RA4E1.

   a. If no Type 6A Pmod is available, ensure that the MCU evaluation kit can use the US082-INTERPEVZ interposer board. Insert the board into the MCU connector before adding any sensor boards.

2. Plug in the QCIOT-ELOADPOCZ board to the Type 6A connector. Be careful to align Pin 1 on the sensor board and MCU kit.

3. If the MCU doesn't have an internal pull-up, connect the J4 and J5 jumpers to place 4.7kΩ pull-up resistors on the I^2C bus lines. RA4E1 has an internal pull-up, so no need to connect any pull-up.

   a. Only one set of I^2C pull-up resistors should be used on the bus. If multiple Pmod connected boards are used, only one board should have the jumpers present.

   b. MCU kits typically do not have pull-up resistors present on the bus lines, but ensure to check for them.

4. Connect the power source to the VIN and GND of connector J3 using wires or terminal pins. If using wires, ensure the wire gauge has sufficient thickness to carry the operating current load. Apply a minimum of 0.8V to VIN. The maximum VIN is dependent on the on-time of the current according to Figure 3.

5. The device is now ready to be used in the system. Follow the MCU kit instructions for connecting and powering up the evaluation kit.
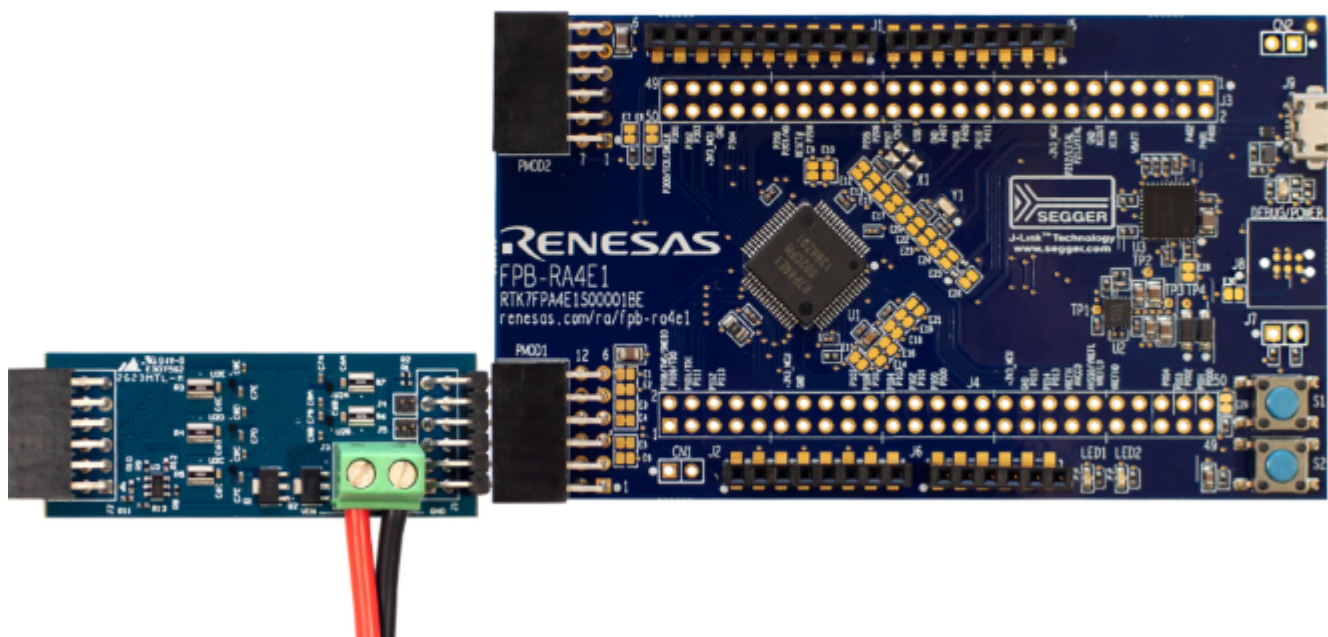

Figure 4. QCIOT-ELOADPOCZ with FPB-RA4E1 MCU Kit

1.2.3 I^2C Address Select

The QCIOT-ELOADPOCZ has a default I^2C address of 0001 000. If this conflicts with another device on the I^2C line, change the first four bits of the I^2C address by writing to register 0x7F of the SLG4BE46142V. This is handled by the included software, but the I^2C address reverts to default after a power down.
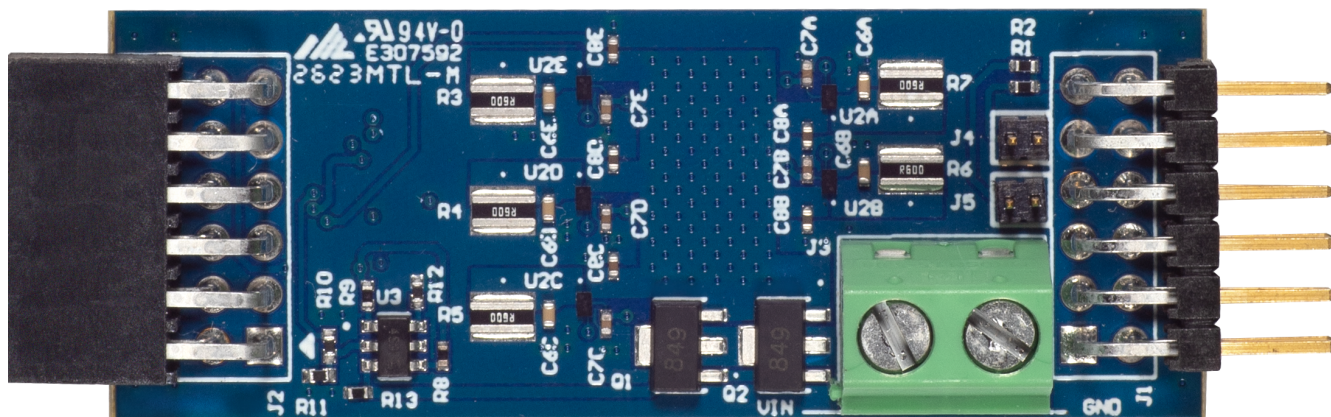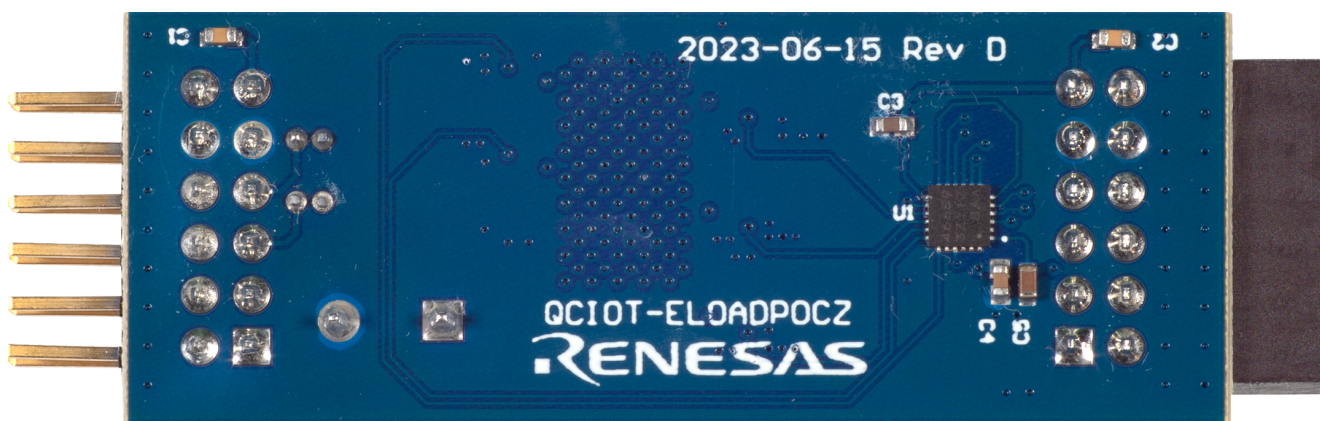
2.   Board Design

Figure 5. QCIOT-ELOADPOCZ (Top)

Figure 6. QCIOT-ELOADPOCZ (Bottom)

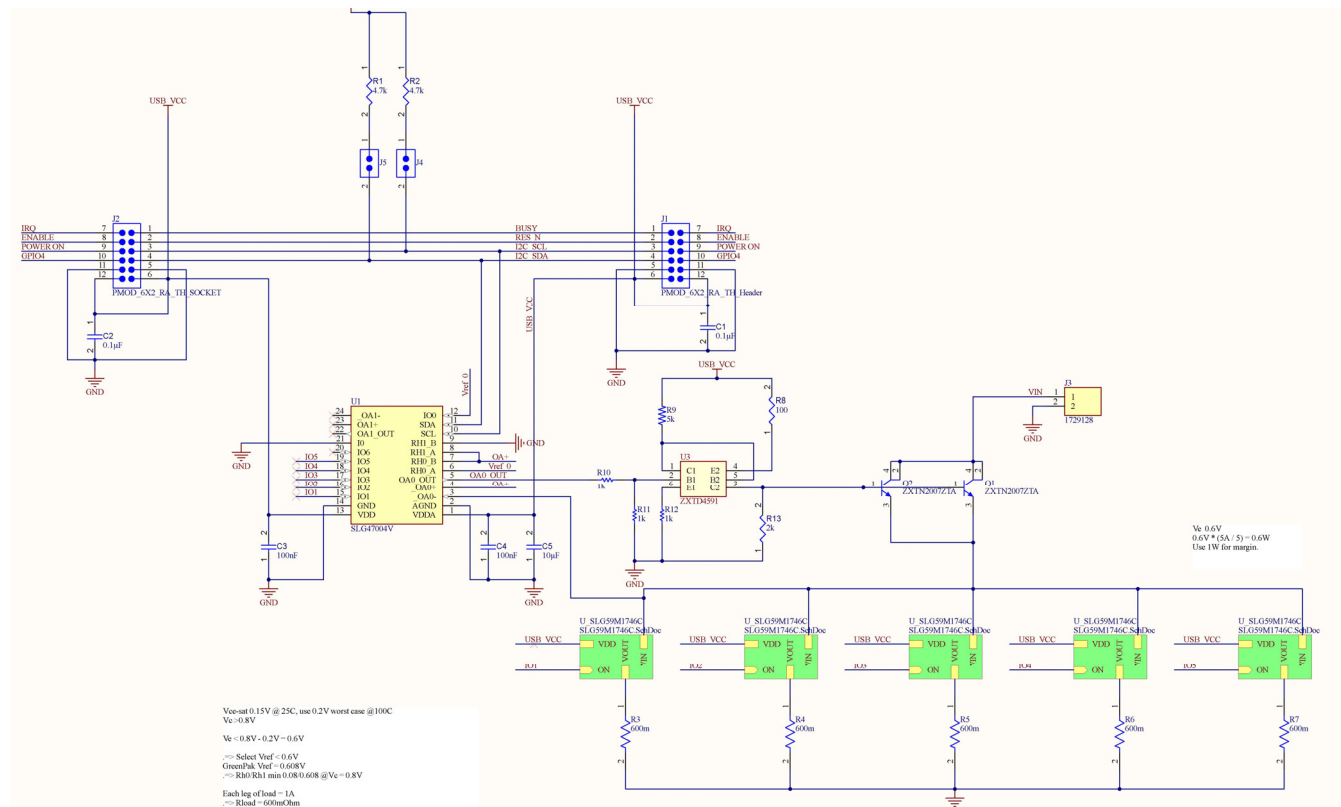## 2.1 Schematic Diagrams

Figure 7. QCIOT-ELOADPOCZ Schematic
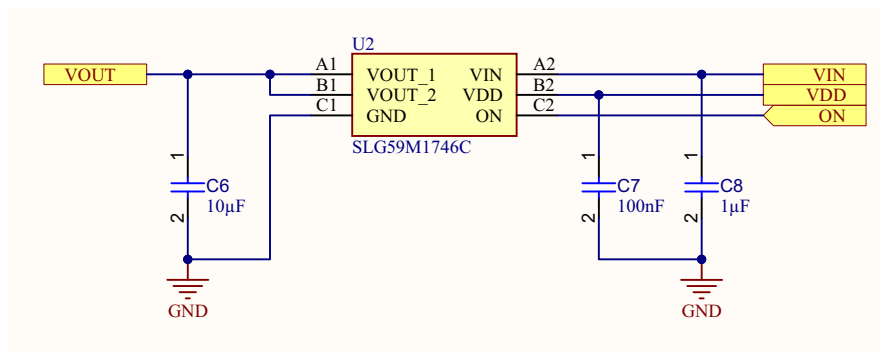

Figure 8. SLG59M1746C Load Switch

2.2   Bill of Materials

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part Number
5	R3, R4, R5, R6, R7	600 mΩ ±1% 1W Chip Resistor Wide 1206 (3216 Metric), 0612 Current Sense Thick Film	Würth Elektronik	561070332080
1	R8	RES 100Ω 1% 1/16W 0402	Yageo	RC0402FR-07100RL
1	R9	Thick Film Resistors - SMD 5 kΩ 62.5mW 0402 1%	Yageo	RC0402FR-075KL
3	R10, R11, R12	RES SMD 1kΩ 1% 1/10W 0402	PANASONIC	ERJ-2RKF1001X
1	R13	RES 2kΩ 1% 1/16W 0402	Stackpole Electronics Inc	RMCF0402FT2K00
1	J3	2 Position Wire to Board Terminal Block Horizontal with Board 0.200" (5.08mm) Through Hole	Phoenix Contact	1729128
2	C1, C2	0.1µF ±10% 10V Ceramic Capacitor X7R 0603 (1608 Metric)	KYOCERA AVX	0603ZC104KAT2A
1	C5	10µF ±10% 16V Ceramic Capacitor X5R 0603 (1608 Metric)	Murata Electronics	GRM188R61C106KAALD
5	C6A, C6B, C6C, C6D, C6E	10µF ±20% 6.3V Ceramic Capacitor X5R 0402 (1005 Metric)	Murata Electronics	GRM155R60J106ME15D
5	C7A, C7B, C7C, C7D, C7E	0.1µF ±5% 16V Ceramic Capacitor X7R 0402 (1005 Metric)	KEMET	C0402C104J4RAC7867
5	C8A, C8B, C8C, C8D, C8E	1µF ±10% 6.3V Ceramic Capacitor X5R 0402 (1005 Metric)	KYOCERA AVX	04026D105KAT2A
2	C3, C4	0.1µF ±10% 50V Ceramic Capacitor X7R 0603 (1608 Metric)	KYOCERA AVX	06035C104KAT2A
2	J4, J5	Connector Header Through Hole 2 position 0.050" (1.27mm)	Samtec Inc.	FTS-102-01-L-S
1	J1	Connector Header Through Hole, Right Angle 12 position 0.100" (2.54mm)	Harwin Inc.	M20-9950645
1	J2	12 Position Receptacle Connector 0.100" (2.54mm) Through Hole, Right Angle Gold	Samtec Inc.	SSW-106-02-F-D-RA
2	R1, R2	4.7 kΩ ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) - Thick Film	Bourns Inc.	CR0402-FX-4701GLF
5	U2A, U2B, U2C, U2D, U2E	Power Switch/Driver 1:1 N-Channel 1A 6-WLCSP (0.71x1.16)	Dialog Semiconductor GmbH	SLG59M1746C
1	U1	ANALOG GREENPAK	Dialog Semiconductor GmbH	SLG47004V

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part Number
1	U3	TRANS NPN/PNP 60V 1A SOT23-6	Diodes Incorporated	ZXTD4591E6TA
2	Q1	Bipolar (BJT) Transistor NPN 30 V 6 A 140MHz 2.1 W Surface Mount SOT-89-3	Diodes Incorporated	ZXTN2007ZTA

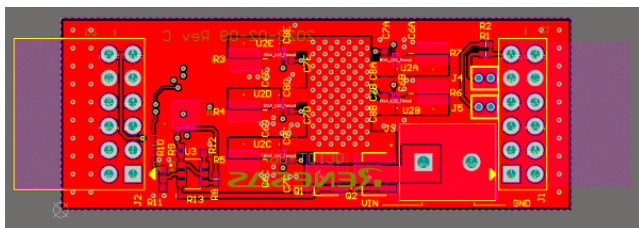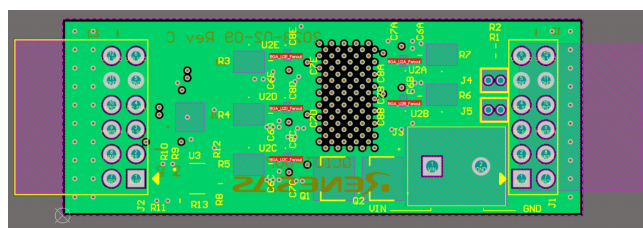## 2.3   Board Layout

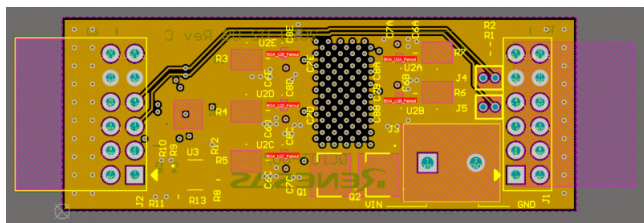Figure 9. Top Layer

Figure 10. Layer 2 (GND)
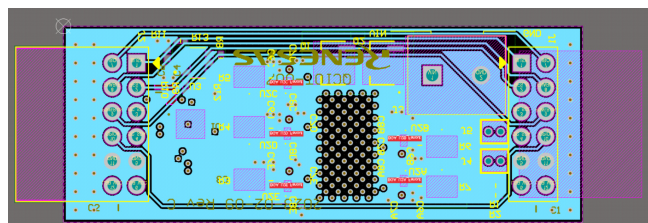

Figure 11. Layer 3 (Signal)
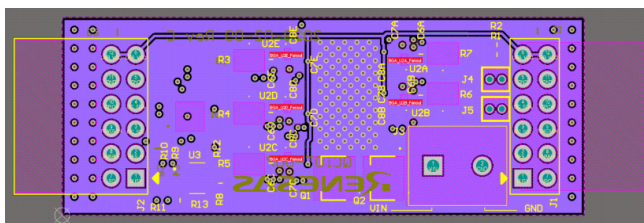

Figure 12. Layer 4 (Signal)
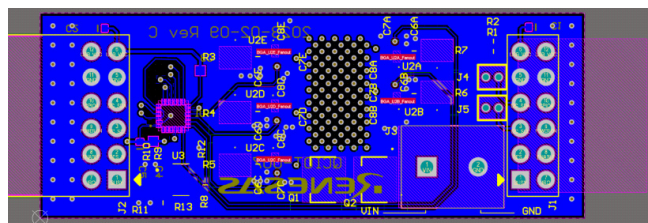

Figure 13. Layer 5 (VIN)

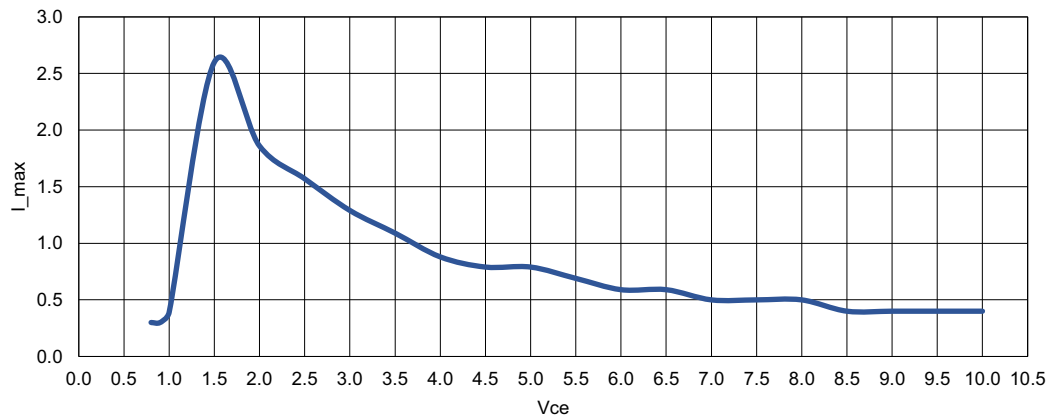Figure 14. Bottom Layer

3. Typical Performance Graphs
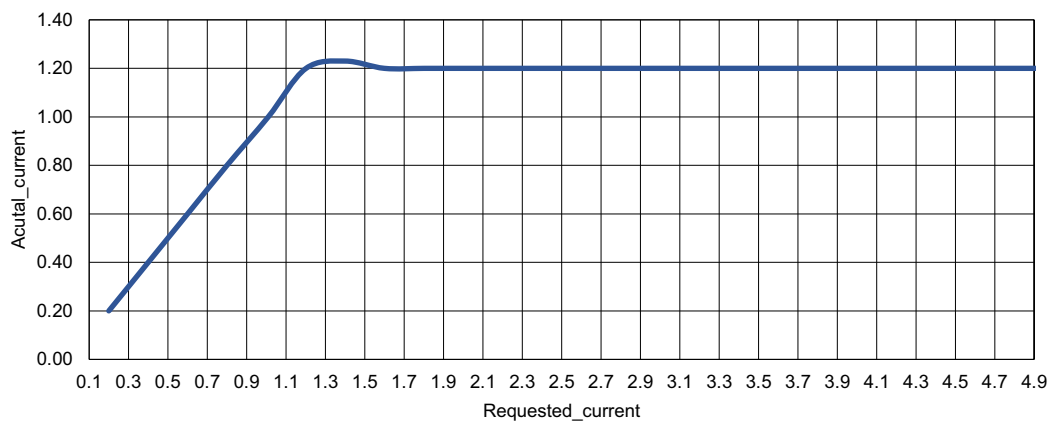

Figure 15. Vce vs I_max

Figure 16. Requested_current vs Actual_current

4. Software Design

The following sections gives an overview of the software implementation for the QCIOT-ELOADPOCZ board, which is based on the Renesas RA Family's Flexible Software Package (FSP). These sections detail the project's code structure, the system's software modules, and the main system flow. Information such as the software API, pin functions, and fault handling is also provided.

4.1 Project Code Structure

The load board project is a highly modular solution, where each device has its own associated module folder that can be easily configured independently of the other modules or ported to other end applications.

The project is split into three modules:

- **DRIVER** – Includes the Communication Layer driver that talks to I^2C.
- **SLG47004V** – Includes the code that interfaces with SLG4BE46142V.
- **SYSTEM** – Main system code that enables the SLG4BE46142V driver and implements system flow.

Each module folder contains the C source files and header files for that module. The SLG module also has an additional Profile header file for specific user configurations. See the User Settings for more details regarding user configurations.

Figure 17 shows the structure of the project in e^2 studio.

ra - includes automatically generated files for FSP drivers

ra_gen - includes main file and generated files for FSP driver settings

src - contains the module code that uses FSP drivers

- DRIVER - I^{2}C communication layer driver code
- SLG47004V - SLG4BE46142V driver code
- SYSTEM - main system code
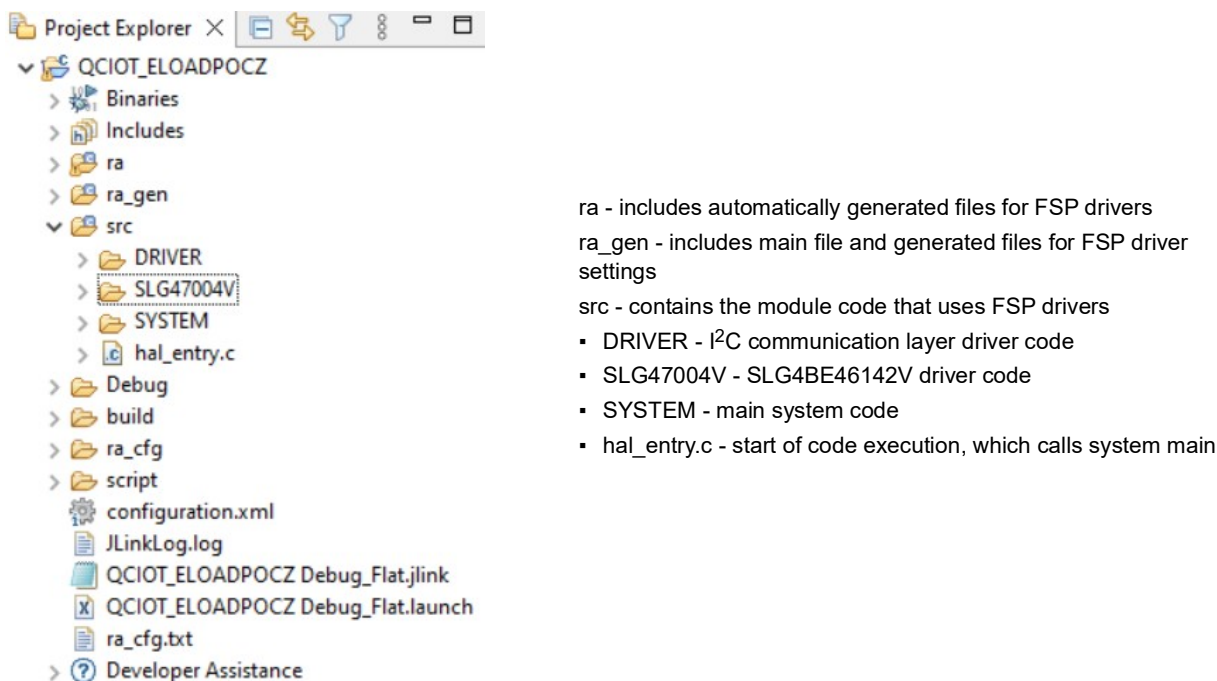- hal_entry.c - start of code execution, which calls system main

Figure 17. Load Board Code Structure

Figure 18 shows the general code structure in terms of its dependencies. Execution begins in hal_entry.c that calls the main function in the system. Next, the main system flow begins, which uses the SLG4700V module to execute the demo. All associated header files reference the lower-level Flexible Software Package (FSP) drivers. System modularity is achieved by routing all calls to SLG module through the system module
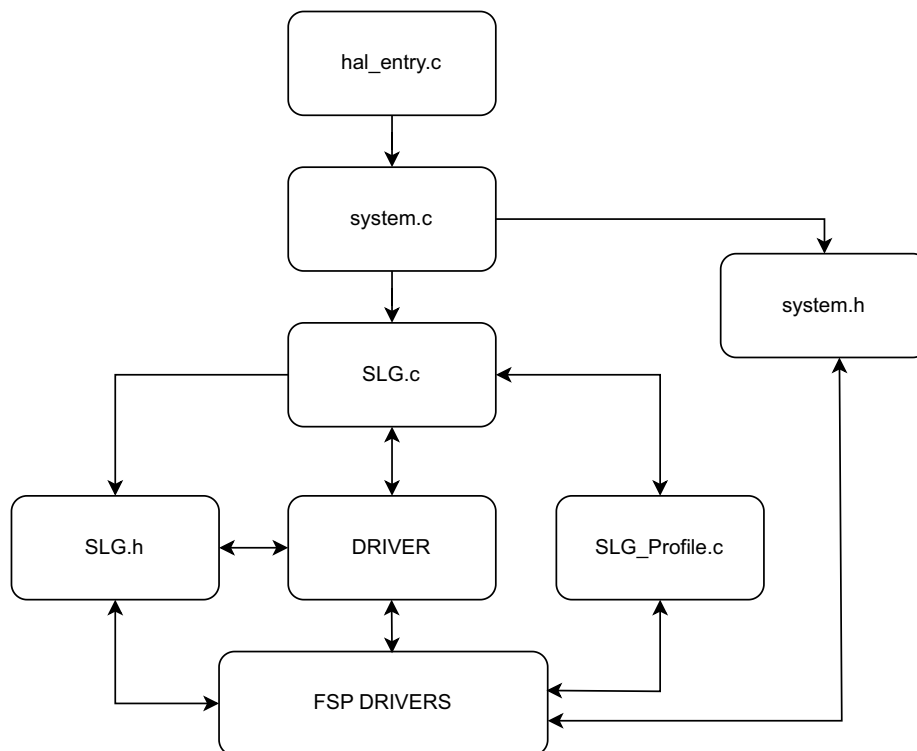

Figure 18. Code Dependency Graph

4.2 Software Module Overview

This software module is responsible for initializing and setting up all the drivers that are used in the main algorithm such as the SLG driver. Also, this module makes calls to the other modules to initialize and setup. After initialization, this module is responsible for taking the current input from the user and turning on the number of switches accordingly. This section outlines the algorithm with a high-level flowchart and descriptions for each step.

4.2.1 Algorithm Flowchart

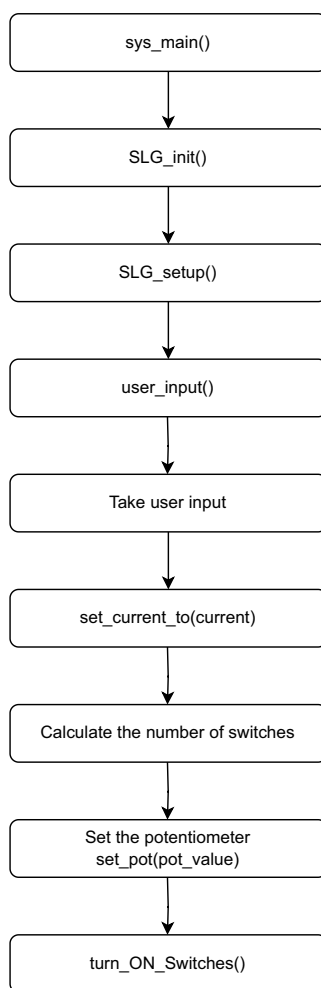Figure 19 describes the algorithm at a high level.

Figure 19. Algorithm Flowchart

The functions outlined in Figure 19 are described as follows:

- sys_main()
  - Calls SLG_init() function.
  - Calls SLG_setup() function.
- SLG_init()
  - Initializes the SLG4BE46142V for I2C communication.
  - Sets the slave address of SLG4BE46142V.
- SLG_setup()
  - Calls user_input() function.

- user_input()
  - Takes the user input.
  - Provides API calls for the user.
  - Using the API call, a user can change the current and slave address and set the delay.
  - Calls the set_current_to (float current) function.
- set_current_to()
  - Calculates the potentiometer value needed to turn ON the switches.
  - Calculates the number of switches needed to be turned ON.
  - Set the potentiometer by calling pot_value() function.
  - Calls the turn_ON_switches() function.
- pot_value()
  - Sets the register C1 and C0 according to the value calculated in set_current_to() function.
- Turn_ON_switches
  - Set the register 7C according to the number of switches calculated in set_current_to() function.

The program starts by initializing the SLG4BE46142V for I^{2}C communication and configuring the slave address. When the initialization is completed, the function SLG_setup() takes the user input where the user can set current, change slave address, and put delay if needed. This user input provides the user with input to create the output profile.

When the output profile is set by the user, a routine is called with the set_current_to() function that calculates the value of potentiometer and the number of switches needed to be turned ON. After the potentiometer value is calculated, it is configured, and the switches are turned ON to get the required output current.

4.2.2   Hierarchy Chart
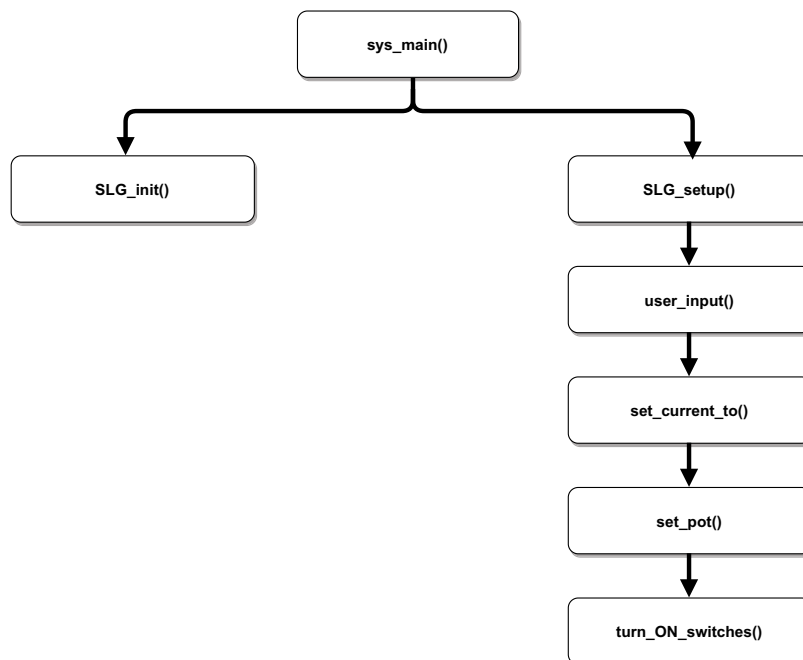
Figure 20 outlines the hierarchy of function calls.

Figure 20. Function Call Hierarchy
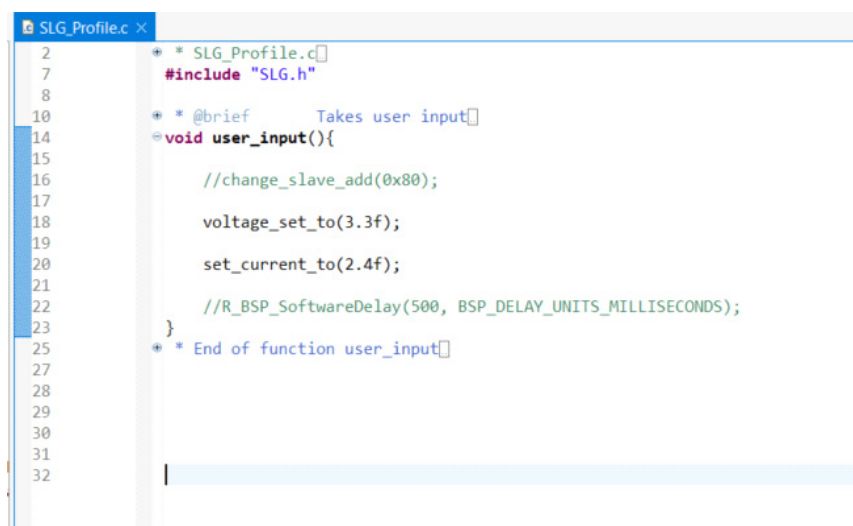
4.3 User Settings

This section outlines the configurable user settings for the project. Configurable settings are included in the SLG_Profile.c file for SLG4BE46142V. A user can use the set_current_to(USER_CURRENT) API to set the output current.

For example, if the user wants to set the current to 1.4A, the API for this is set_current_to(1.4f).

Similarly, change the voltage_set_to(USER_VOLTAGE) API to the applied voltage of the board.

Note: The output is limited to 4W.

Figure 21 shows the contents of the Profile header file.

Figure 21. Profile Header Files

5. Ordering Information

Part Number	Description
QCIOT-ELOADPOCZ	QCIOT-ELOADPOCZ Load Board

6. Revision History

Revision	Date	Description
1.05	May 29, 2024	Updated Figure 4.
1.04	Mar 28, 2024	▪ Updated version in section 1.2.1 Software Installation and Usage. ▪ Updated item 3 in section 1.2.2 Kit Hardware Connections. ▪ Updated bullet items in section 4.1 Project Code Structure. ▪ Updated Figure 17 and associated notes. ▪ Updated Figure 18. ▪ Changed user settings file name reference to "SLG_Profile.c file" from "SLG_Profile.h header file" in section 4.3.
1.03	Feb 13, 2024	▪ Removed references to QCIOT-007 in the document title and on pages 4 and 5. ▪ Changed orderable part number to QCIOT-ELOADPOCZ from QCIOT-007.
1.02	Jan 5, 2024	▪ Updated Figure 1, Figure 4 and Figure 5. ▪ Changed "QCIOT-007 Load Board" to "QCIOT-ELOADPOCZ" throughout the document.
1.01	Oct 24, 2023	Updated part number to QCIOT-007.
1.00	Dec 21, 2022	Initial release

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