

TI Designs: TIDA-01400

bq76PL455A-Q1 通信ブリッジのリファレンス・デザイン



概要

TIDA-01400は専用のbq76PL455A-Q1デバイスを使用し、システムのマイクロコントローラ(MCU)と、bq76PL455A-Q1バッテリー監視デバイスのデジタイズ・チェーンされたスタックとの間で、通信インターフェイスとして機能します。専用のbq76PL455A-Q1を使用することで、パック・コントローラはデジタイズ・チェーン通信構造の利点を十分に活用でき、バッテリー・パックとの通信が簡素化されるとともに、パックに発生する可能性のある高電圧からパック・コントローラが絶縁されます。また、TIDA-01400には完全に絶縁された2つのアンプが組み込まれており、絶縁されたパックの電流センシングを行うとともに、独立した絶縁電圧測定が可能です。

リソース

[TIDA-01400](#)

[bq76PL455A-Q1](#)

[TPS61093](#)

[TPD4E05U06QDQARQ1](#)

[SN6501DBVR](#)

[TPS76350DBVR](#)

[TPS7A1650DGNR](#)

[AMC1200BDUBR](#)

[bq76PL455 EVM](#)

[デザイン・フォルダ](#)

[プロダクト・フォルダ](#)

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[ツール・フォルダ](#)

特長

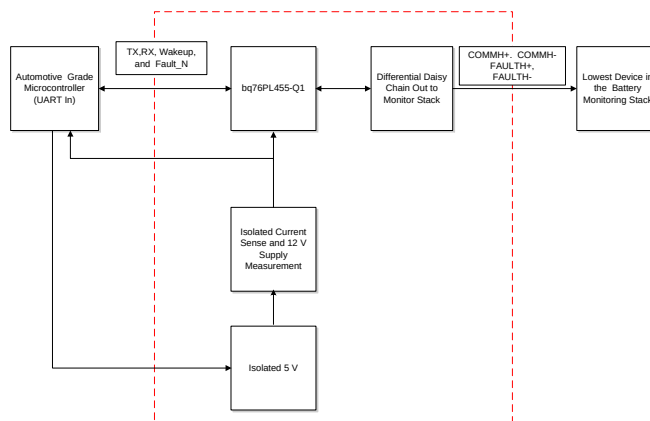
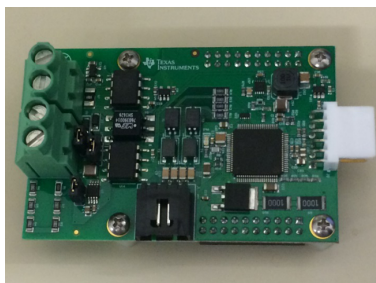
- TMS570または C2000™ 車載用グレードMCUと互換
- 完全に絶縁されたパック電流とユーザーの選択した電圧の測定値を、MCUまたはbq76PL455A-Q1のAUXピンへ送信
- 既存のMCU電源から12Vレールでbq76PL455A-Q1に電力を供給
- 絶縁されたデジタイズ・チェーン通信出力によりバッテリー・パックと通信

アプリケーション

- 電気自動車およびハイブリッド電気自動車
- 電動アシスト自転車および電動スクーター
- エネルギー・ストレージおよびUPS



[E2Eエキスパートに質問](#)





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1 System Overview

1.1 System Description

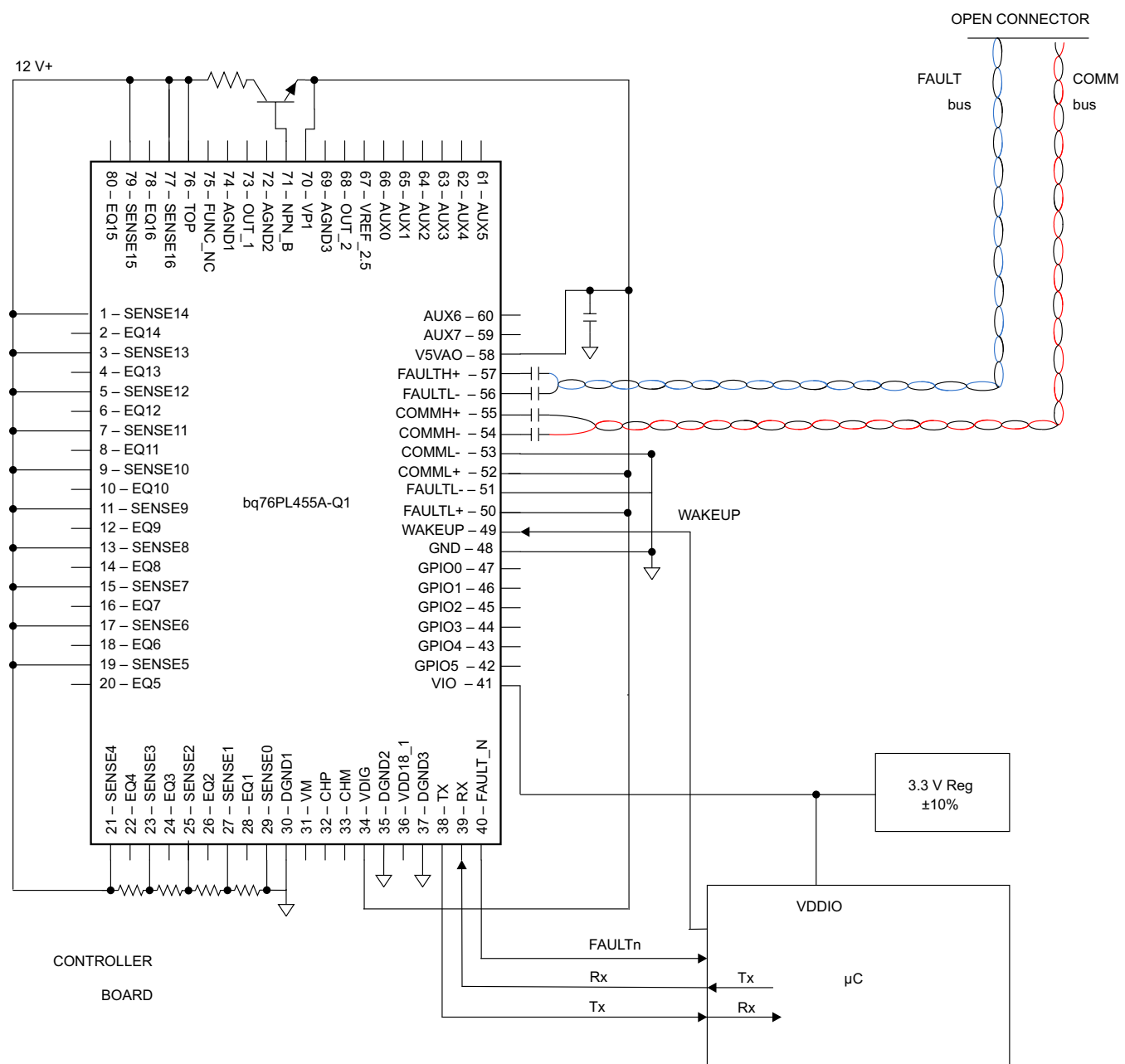
The bq76PL455A-Q1 acts as a communication bridge between a system controller's or battery pack controller's UART commands into the differential daisy-chain protocol used by the bq76PL455A-Q1 stack used for battery pack monitoring. Universal asynchronous receiver and transmitter (UART) communication takes place on the TX and RX pins as well as an interrupt pin FAULT_N, which is used to alert the MCU of a device fault in the battery monitoring stack. A fourth pin, WAKEUP, transitions the device from its shutdown mode. The device acting as the bridge sends commands to the stack through the COMMH+, COMMH-, FAULTLH+, and FAULTLH- connections.

The bq76PL455A-Q1 requires a minimum of 12 V of power. In a typical application the bq76PL455A-Q1 derives power from the battery stack. When used as a communication bridge, the bq76PL455A-Q1 will typically be on the same board as the pack controller, which is isolated from the battery stack. TIDA-01400 implements a 12-V boost converter with the TPS61093, which allows the bq76PL455A-Q1 to be powered from the same source as the controller.

TIDA-01400 incorporates two AMC1200BDUBR isolated fully-differential amplifiers to sense current passing through the pack as well as an isolated-voltage measurement. These values are then reported back to the MCU and the AUX inputs of the bq76PL455A-Q1.

Using a dedicated bq76PL455A-Q1 allows the pack controller to take full advantage of the daisy-chain communication structure and simplifies the process of communicating to the battery pack, while isolating the pack controller from potentially high battery pack voltages

1.2 Block Diagram



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図 1. System Block Diagram

1.3 Highlighted Products

1.3.1 bq76PL455A-Q1

The bq76PL455A-Q1 device is an integrated 16-cell battery monitoring and protection device, which is designed for high-reliability automotive applications. The integrated high-speed, differential, capacitor-isolated communications interface allows up to 16 bq76PL455A-Q1 devices to communicate with a host through a single high-speed UART interface. The bq76PL455A-Q1 monitors and detects several different fault conditions, which includes overvoltage, undervoltage, overtemperature, and communication faults. Six GPIO ports and eight analog AUX analog-to-digital converter (ADC) inputs are included for additional monitoring and programmable functionality. A secondary thermal shutdown is included for further protection.

1.3.2 TPS61093

The TPS61093 is a 1.2-MHz, fixed-frequency boost converter designed for high integration and high reliability. The IC integrates a 20-V power switch, input-output isolation switch, and power diode. When the output current exceeds the overload limit, the isolation switch of the IC opens up to disconnect the output from the input, thus protecting the IC and the input supply. The isolation switch also disconnects the output from the input during shutdown to minimize leakage current. When the IC is shut down, the output capacitor is discharged to a low-voltage level by internal diodes. Other protection features include 1.1-A peak overcurrent protection (OCP) at each cycle, output overvoltage protection (OVP), thermal shutdown, and undervoltage lockout (UVLO).

1.3.3 TPD4E05U06QARQ1

The TPDxE05U06-Q1 is a family of unidirectional transient voltage suppressor (TVS) electrostatic discharge (ESD) protection diodes with ultra-low capacitance. The devices are rated to dissipate ESD strikes above the maximum level specified in the IEC 61000-4-2 level four international standard. The ultra-low-loading capacitance makes these devices ideal for protecting any high-speed signal applications up to 6 Gbps.

1.3.4 SN6501DBVR

The SN6501 is a monolithic oscillator and power-driver, specifically designed for small form factor, isolated power supplies in isolated interface applications. The device drives a low-profile, center-tapped transformer primary from a 3.3-V or 5-V DC power supply. The secondary can be wound to provide any isolated voltage based on transformer turns ratio. The SN6501 consists of an oscillator followed by a gate drive circuit that provides the complementary output signals to drive the ground referenced N-channel power switches. The internal logic ensures break-before-make action between the two switches.

1.3.5 TPS76350DBVR

The TPS763xx family of low-dropout (LDO) voltage regulators offers the benefits of LDO voltage, low-power operation, and miniaturized packaging. These regulators feature LDO voltages and quiescent currents compared to conventional LDO regulators. Offered in a 5-pin, small outline integrated-circuit SOT-23 package, the TPS763xx series devices are ideal for cost-sensitive designs and for applications where board space is at a premium. A combination of new circuit design and process innovation has enabled the usual pnp pass transistor to be replaced by a P-channel MOS (PMOS) pass element. Because the PMOS pass element behaves as a low-value resistor, the dropout voltage is low—typically 300 mV at 150 mA of load current (TPS76333)—and is directly proportional to the load current. Because

the PMOS pass element is a voltage-driven device, the quiescent current is low (140-μA maximum) and is stable over the entire range of output load current (0 mA to 150 mA). Intended for use in portable systems such as laptops and cellular phones, the LDO voltage feature and low-power operation results in a significant increase in system battery operating life. The TPS763xx also features a logic-enabled sleep mode to shut down the regulator, which reduces quiescent current to 1-μA maximum at T_J = 25°C. The TPS763xx is offered in 1.6-V, 1.8-V, 2.5-V, 2.7-V, 2.8-V, 3-V, 3.3-V, 3.8-V, and 5-V fixed-voltage versions.

1.3.6 TPS7A1650DGNR

The TPS7A16 family of ultra-low-power, ILDO voltage regulators offers the benefits of ultra-low quiescent current, high-input voltage, and miniaturized, high thermal-performance packaging. The TPS7A16 family is designed for continuous or sporadic (power backup) battery-powered applications where ultra-low quiescent current is critical to extending system battery life. The TPS7A16 family offers an enable pin (EN) compatible with standard CMOS logic and an integrated open drain active-high power good output (PG) with a user-programmable delay. These pins are intended for use in MCU-based, battery-powered applications where power-rail sequencing is required.

1.3.7 AMC1200BDUBR

The AMC1200 and AMC1200B are precision-isolation amplifiers with an output separated from the input circuitry by a silicon dioxide (SiO₂) barrier that is highly resistant to magnetic interference. This barrier has been certified to provide galvanic isolation of up to 4250 VPEAK (AMC1200B) or 4000 VPEAK (AMC1200) according to UL1577 and VDE V 0884-10. Used in conjunction with isolated power supplies, these devices prevent noise currents on a high common-mode voltage line from entering the local ground and interfering with or damaging sensitive circuitry. The input of the AMC1200 or AMC1200B is optimized for direct connection to shunt resistors or other low-voltage level signal sources. The excellent performance of the device supports accurate current control resulting in system-level power saving and, especially in motor-control applications, lower torque ripple. The common-mode voltage of the output signal is automatically adjusted to either the 3-V or the 5-V low-side supply.

1.4 Design Considerations

1.4.1 bq76PL455A-Q1

For bq76PL455A detailed design considerations, see the *bq76PL455A-Q1 Design Recommendations*[6] application report.

When using the AUX pins to monitor a voltage, such as the output of the AMC1200B isolated amplifier, 式 1 can be used to convert between the voltage at the AUX pin and the ADC reading.

$$V_{\text{Aux}} = \frac{2 V_{\text{ref}}}{65535} \times \text{ADC_Read_Value} \quad (1)$$

1.4.2 12-V Boost Converter

For a detailed design procedure of the boost converter, see Section 9.2.1.2 of the *TPS61093 Low-Input Boost Converter With Integrated Power Diode and Input/Output Isolation*[4] datasheet..

1.4.3 Isolated-Current Sense and Voltage Measurements

For a detailed procedure of generating the isolated 5-V power supply, see the *SN6501 Transformer Drive for Isolated Supplies* datasheet[3].

When using the ACM1200B isolated op-amp, a differential-input voltage of no more than 250 mV should be applied to the VINP and VIN- pins to prevent the output from clipping. The output voltage should also be considered as it is possible for the op-amp to generate more than 3.3 V at the output when using an isolated 5-V supply. If an MCU is used to monitor the voltages, the voltage can exceed the maximum voltage rating of the pins and damage the part. The bq76PL455A-Q1 AUX pins are rated to 5 V, so no damage should occur.

When designing the input-resistor networks, note that the op-amp will have a gain of four if using the op-amp in a single-ended mode of operation, and there will be a 2.55-V offset at the output. Using the 100-mΩ shunt resistor on the board means that largest current that can be sensed without damaging the 3.3-V pin on the MCU is 1.875 A. This current can be found using 式 2.

$$\text{Max Sense Current} = \frac{3.3 - 2.5}{4 \times R_{\text{SHUNT}}} \quad (2)$$

In general, the pack current can always be determined by replacing 3.3 V with the sampled ADC value and R_{shunt} with the desired shunt resistance.

A second AMC1200B is provided to allow for an isolated-voltage measurement. A simple voltage divider can be used to sample the desired voltage, but the user must scale the resistor divider according to the voltage to be measured. For example, TIDA-01400 is currently set up to measure an external 12-V supply using 50 kΩ of series resistance, and 499 Ω of shunt resistance across the input terminals of the op-amp. The voltage detected by the MCU or bq76PL455A-Q1 can be calculated by 式 3.

$$V_{\text{sense}} = 2.55 + 4 \frac{R_{\text{shunt}}}{R_{\text{shunt}} + R_{\text{stack}}} \quad (3)$$

If measuring a larger voltage such as the pack voltage, the resistor divider must be scaled so that the 250-mV maximum input-voltage requirement is satisfied.

WARNING

TIDA-01400 was designed with intentions to measure a separate 12-V battery to be used in active cell balancing. If modifying the design to measure high voltages, use proper safety precautions.

By default, two 0Ω resistors are present on the isolated side of the board. Resistor R32 connects the two ground planes at a single point, while resistor R33 connects the ISO_SUP net to the PISO_5V net, powering the op-amp U8. These resistors should be left on when measuring voltage and current of the same battery or pack. If measuring current from one battery, a separate 12V battery for active cell balancing for example, and pack voltage then resistors R32/R33 should be removed, and jumpers J5/J6 should be placed. In this configuration, both measurement circuits will be fully isolated from each other, as well as the MCU/455 bridge circuitry. 表 1 summarizes the jumper and resistor configurations required for having both amplifiers isolated together or separately. A situation with both the resistors and jumpers on should be avoided as a precaution.

表 1. Isolation Jumper Configurations

ISOLATION CONFIGURATION	J5	J6	R32/R33	COMMENT
Voltage and current from same battery	OFF	OFF	ON	Default

表 1. Isolation Jumper Configurations (continued)

ISOLATION CONFIGURATION	J5	J6	R32/R33	COMMENT
Current and voltage of separate batteries	ON	ON	REMOVE	Both measurement circuits isolated from each other.
—	ON	ON	ON	Avoid this situation.

2 Getting Started Hardware and Software

2.1 Hardware

- GW INSTEK SPD-3606 dual-range DC-power supply
- KIKUSUI PLZ1004W electronic load
- bq76PL455A-Q1 communication bridge board
- bq76PL455A EVM
- Resistor ladder board
- USB-serial cable

2.2 Software

- bq76PL455A EVM GUI

3 Testing and Results

3.1 Communications Bridge

To set up the communications bridge board, several connections must be made:

- Connect the communication bridge board to the PC with a USB-serial cable.
- Connect the bridge board high-side differential communication head to the bq76PL455A EVM low-side differential communication header.
- Connect the GW INSTEK power supply to a resistive load board, emulating a 16-S battery connection. Set the voltage to 61.2 V.

☒ 2 summarizes these connections

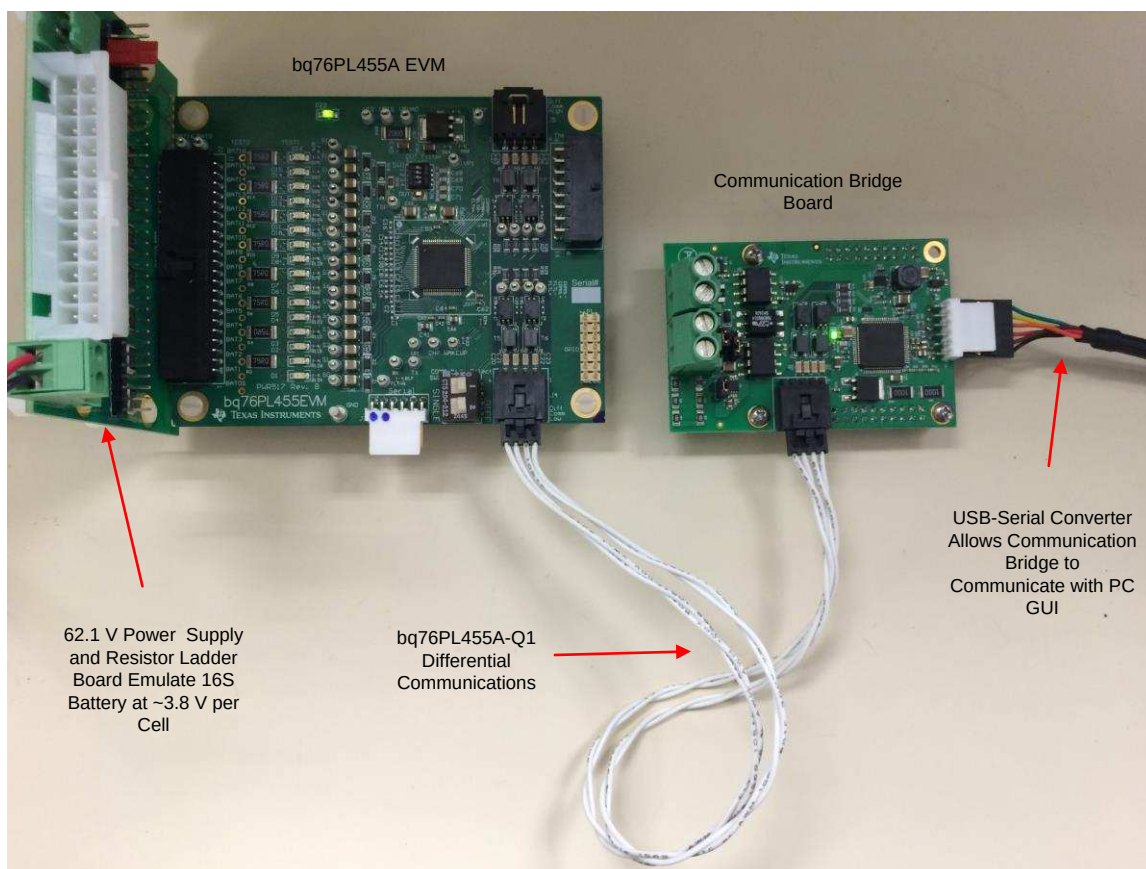


図 2. Communication Bridge Board Setup

After setting up the boards, open the bq76PL455A EVM GUI. After selecting the appropriate COM port, a dialog box confirming that two bq76PL455A devices were detected will appear. 図 3 shows this dialog box.



図 3. bq76PL455A GUI Detecting Two Board Stack

To communicate with the bq76PL455A that is monitoring the cells, board one should be selected. This selection will tell the GUI to communicate to the second board in the stack by translating the UART commands into the proprietary daisy-chain protocol. 図 4 demonstrates selecting board address one.

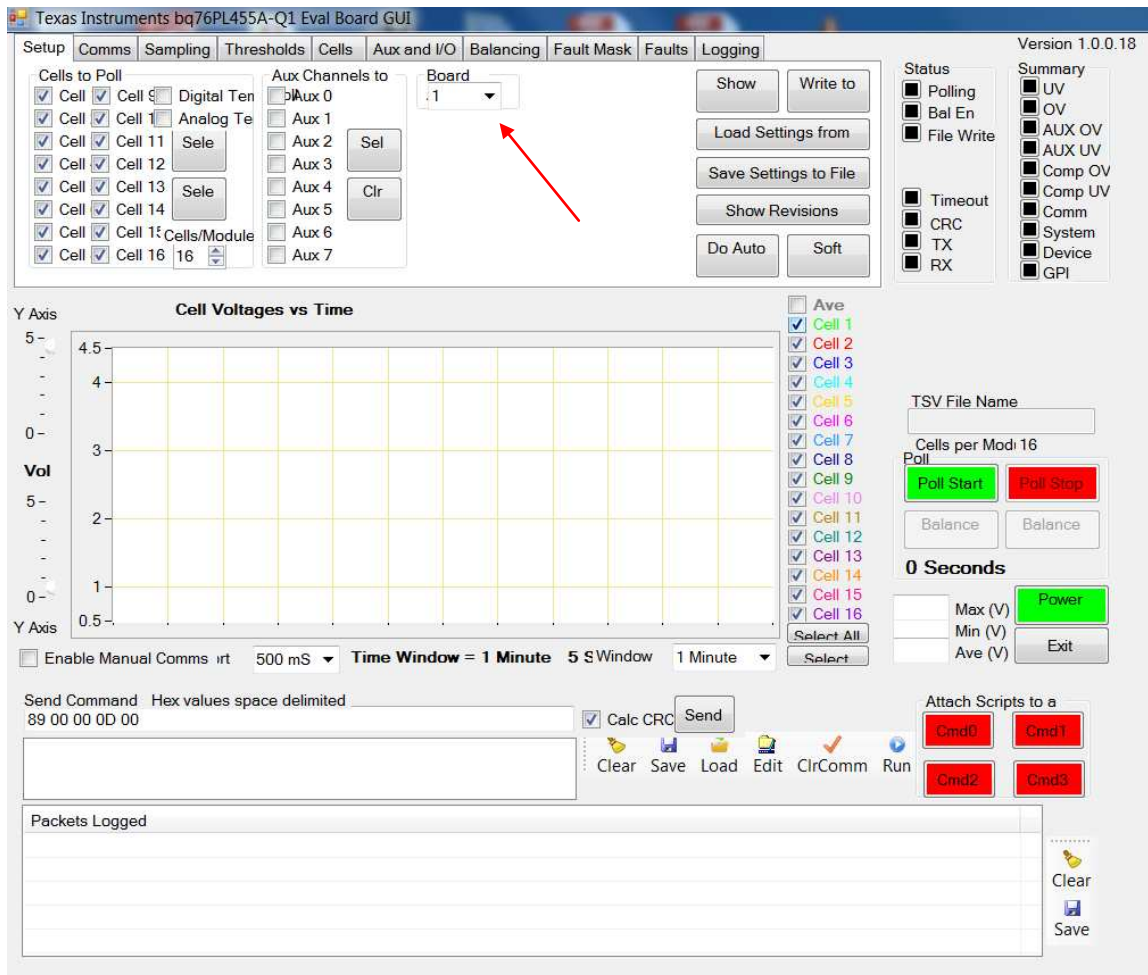


図 4. Addressing Top of the Stack Through the Bridge

Next move to the *Cell* tab, and click the *Poll Start* button, which is demonstrated in 図 5. If the correct board is addressed and the resistor ladder is set up so 1/16th of the voltage is detected at each branch, the board should report those cell voltages back to the GUI through the communication bridge .

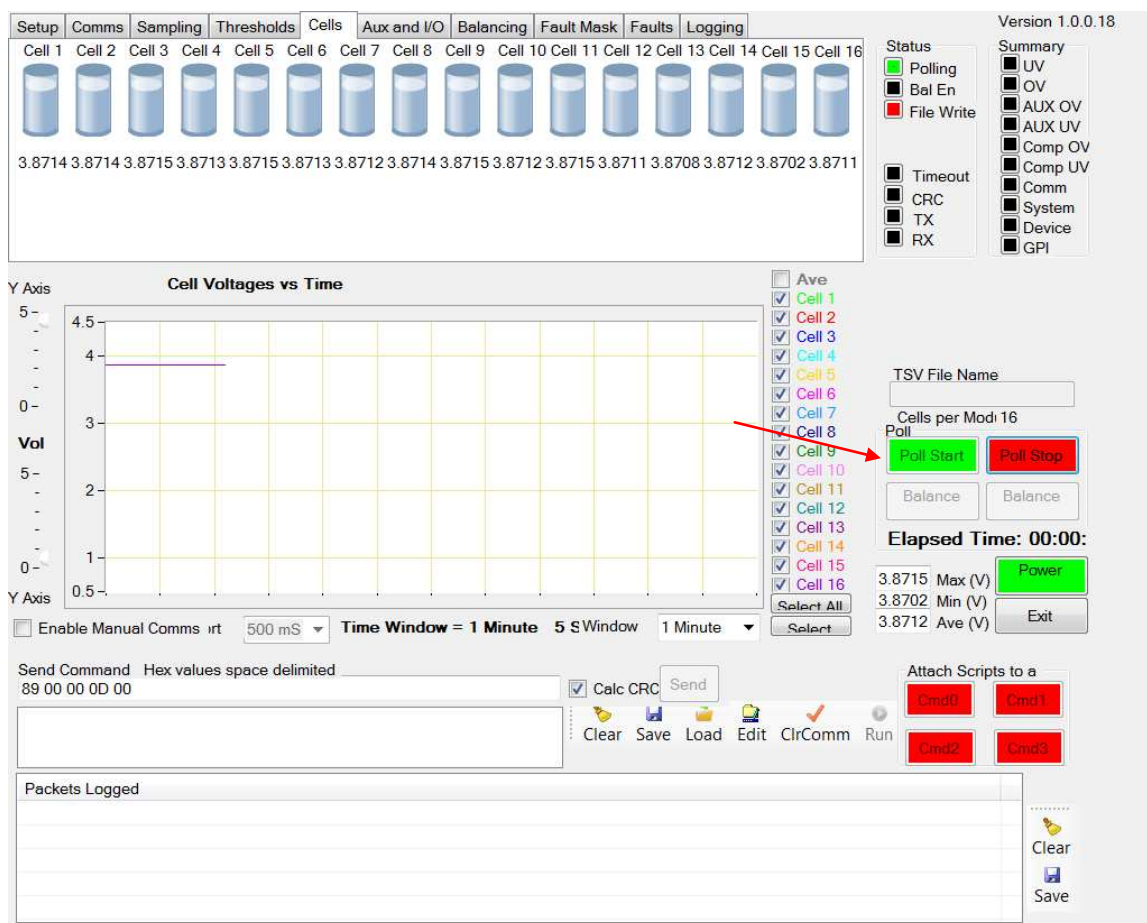


図 5. Reporting Cell Voltage to GUI Through Bridge

The bq76PL455A-Q1 communication bridge was developed to be a BoosterPack™, so firmware can be developed on an automotive-grade MCU, such as the TMS570 or C2000, once a project is mature enough.

3.2 Isolated-Voltage Measurement

To set up the isolated-voltage measurement, the bq76PL455A-Q1 communication bridge board must be connected to the GUI through a USB-serial connection. The voltage to be measured must also be connected to header J3, as seen in [Figure 6](#).

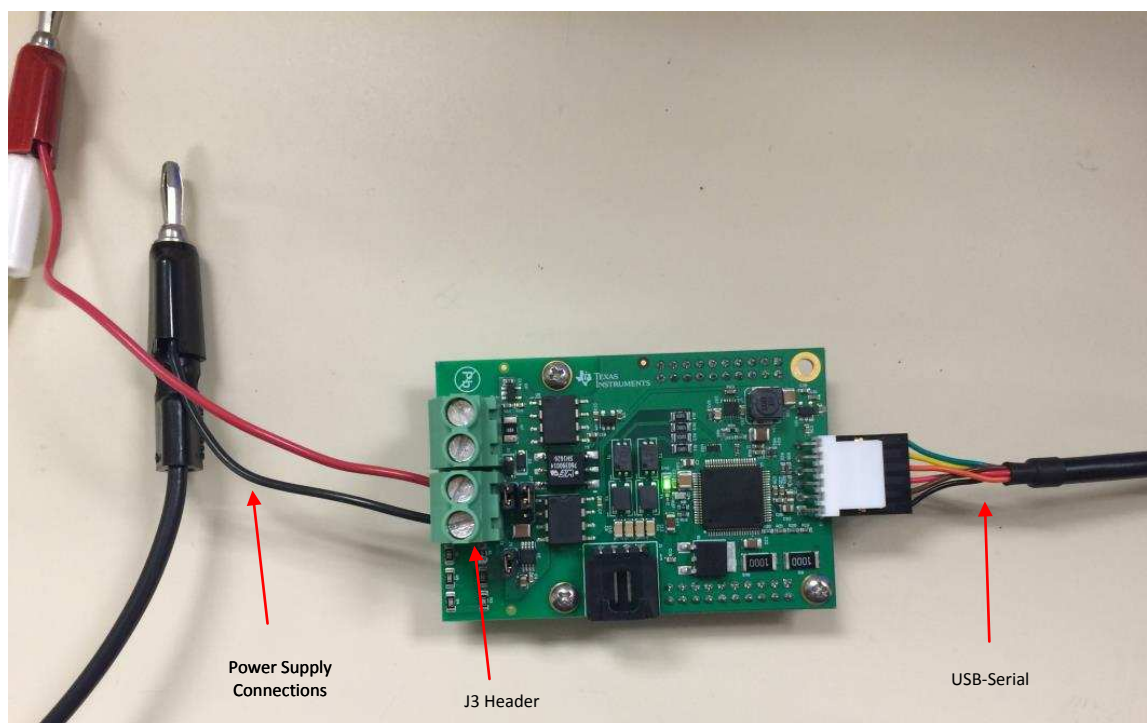


Figure 6. Isolated-Voltage Measurement Setup

Once the board has been set up, the bq76PL455A GUI must be set up to read the voltage reported by the AMC1200B isolated op-amp. To do so, the GUI must be opened and *Board 0* selected if there are more boards than just the communication bridge in the stack. Because the communication bridge is isolated from the cells and powered by a 12-V boost converter, all cell measurements can be deselected, and AUX0 should be enabled. 図 7 shows the proper setup of the GUI.

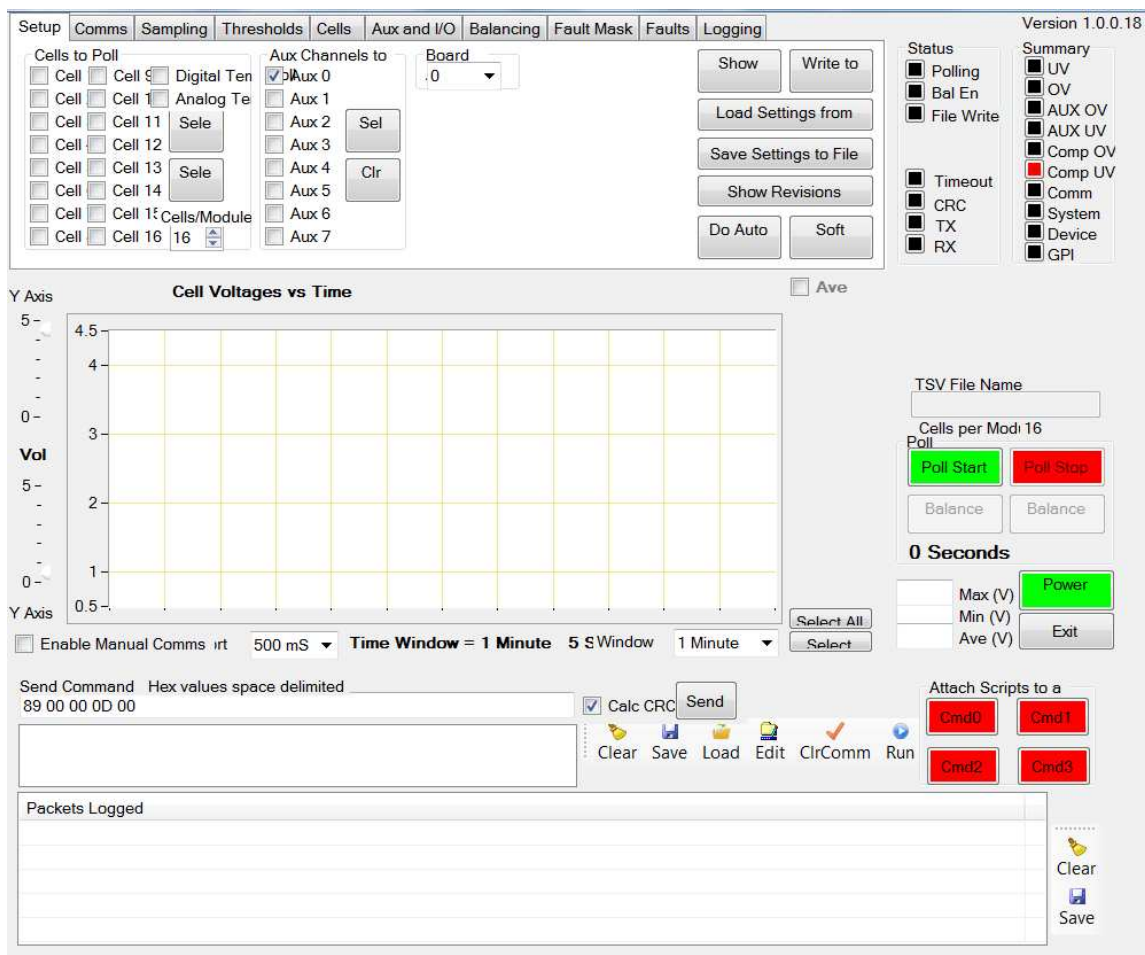
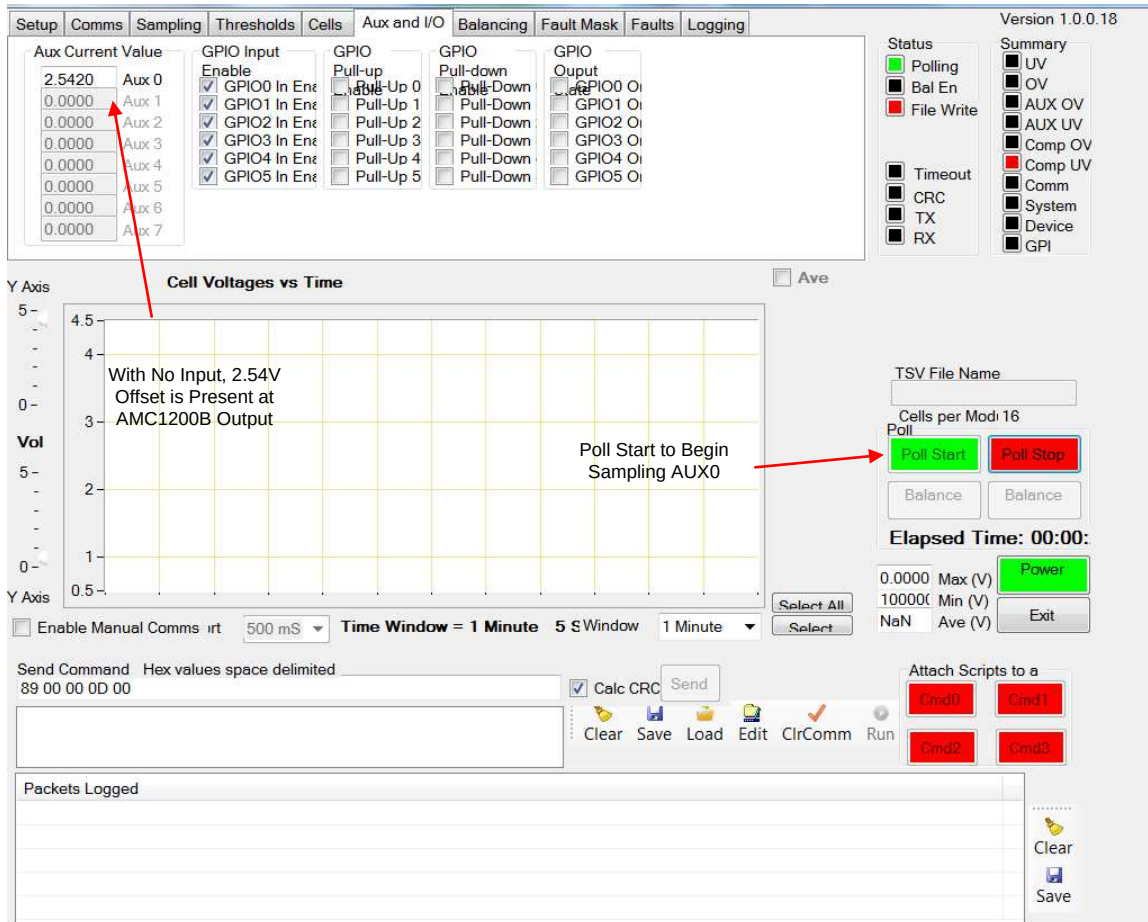
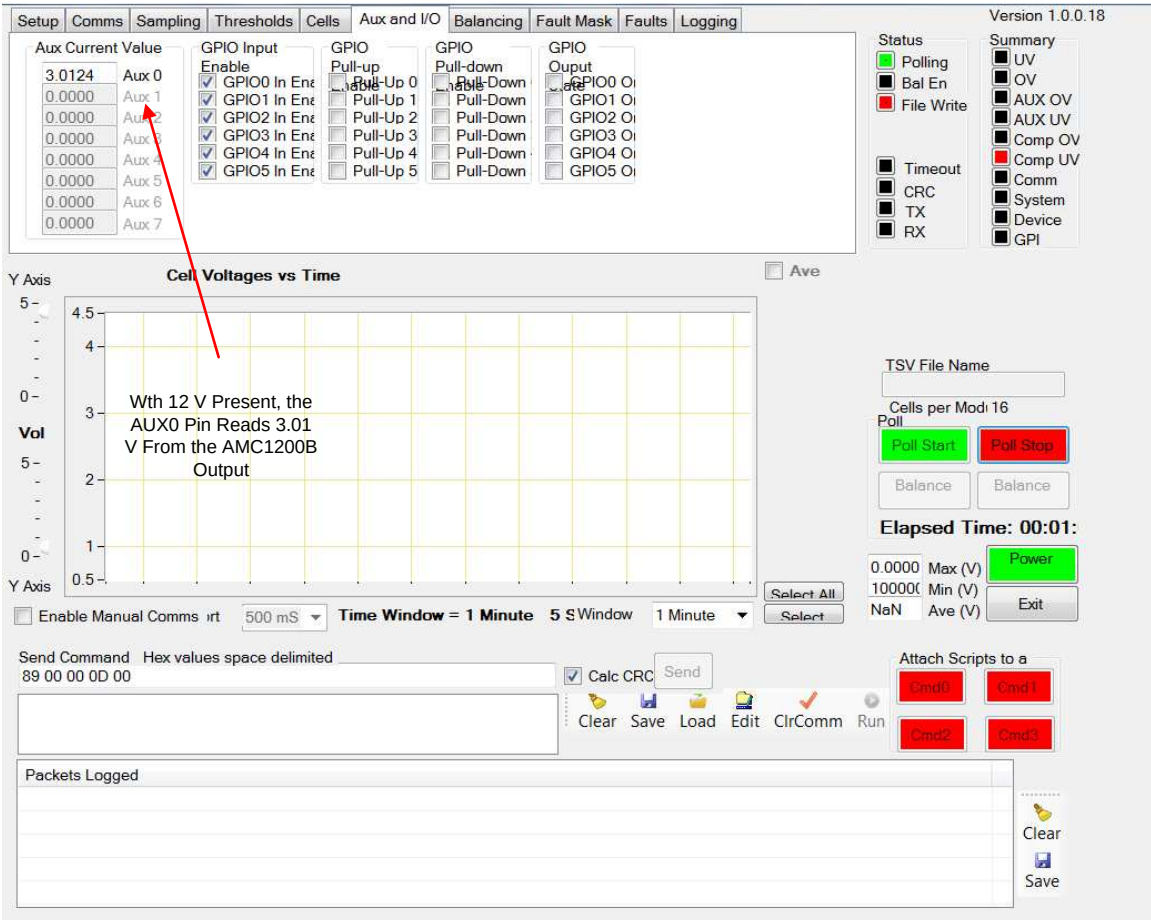


図 7. GUI Setup for Isolated Voltage Measurement

Moving to the *Aux and I/O* tab and then clicking the *Poll Start* button will cause the bq76PL455A-Q1 to begin sampling the AUX0 pin, which is connected to the output of an AMC1200B isolated op-amp. The AMC1200B has a 2.54-V offset at the output, which AUX0 should measure with no input attached to J3, as shown in 8.



8. AUX0 Reading With No Input Voltage

Connecting the GW INSTEK DC power supply to J3 will allow the user to apply a voltage to the voltage divider present at the input of the AMC1200B. TIDA-01400 has been set up to measure a separate 12-V battery used for active cell balancing. To ensure that the 250-mV input voltage limit of the AMC1200B is not violated, the input resistor network has been set up with 50-k Ω of series resistance and a 499- Ω shunt resistance.  9 shows that AUX0 measures roughly 3 V with 12 V present.

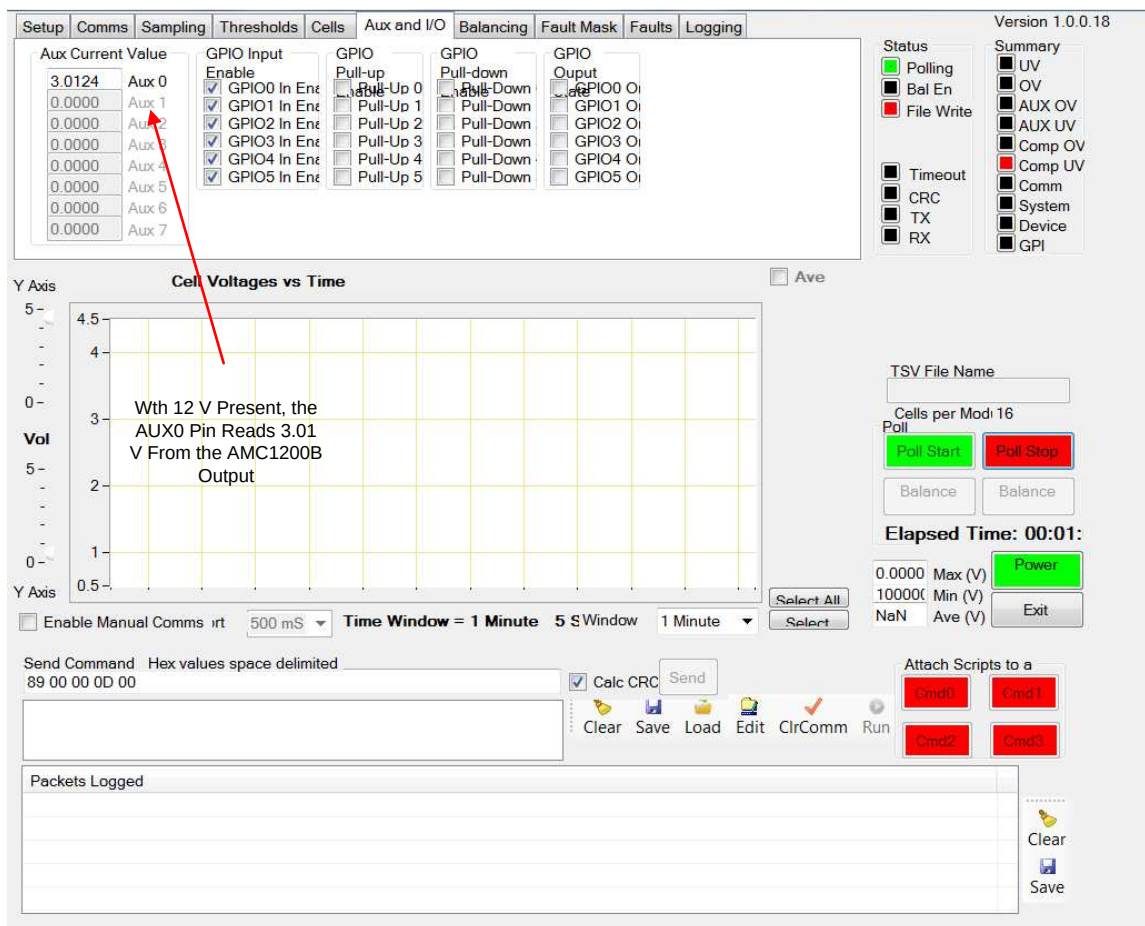


図 9. AUX0 Reading With 12-V Input

If a larger voltage, such as the pack voltage, is going to be measured the resistor divider should be scaled accordingly. Failure to scale the resistor divider can result in a voltage larger than 3.3 V at the output of the AMC1200B, which can result in damage to some MCUs.

3.3 Isolated Current-Sense Measurement

TIDA-01400 also offers a second AMC1200B for dedicated current-sense measurements. To test the current-sense measurement, an electronic load was used to draw current from the GW INSTEK DC power supply with an onboard 10-m Ω shunt resistor connected in series with the load. [Figure 10](#) shows the board connections.

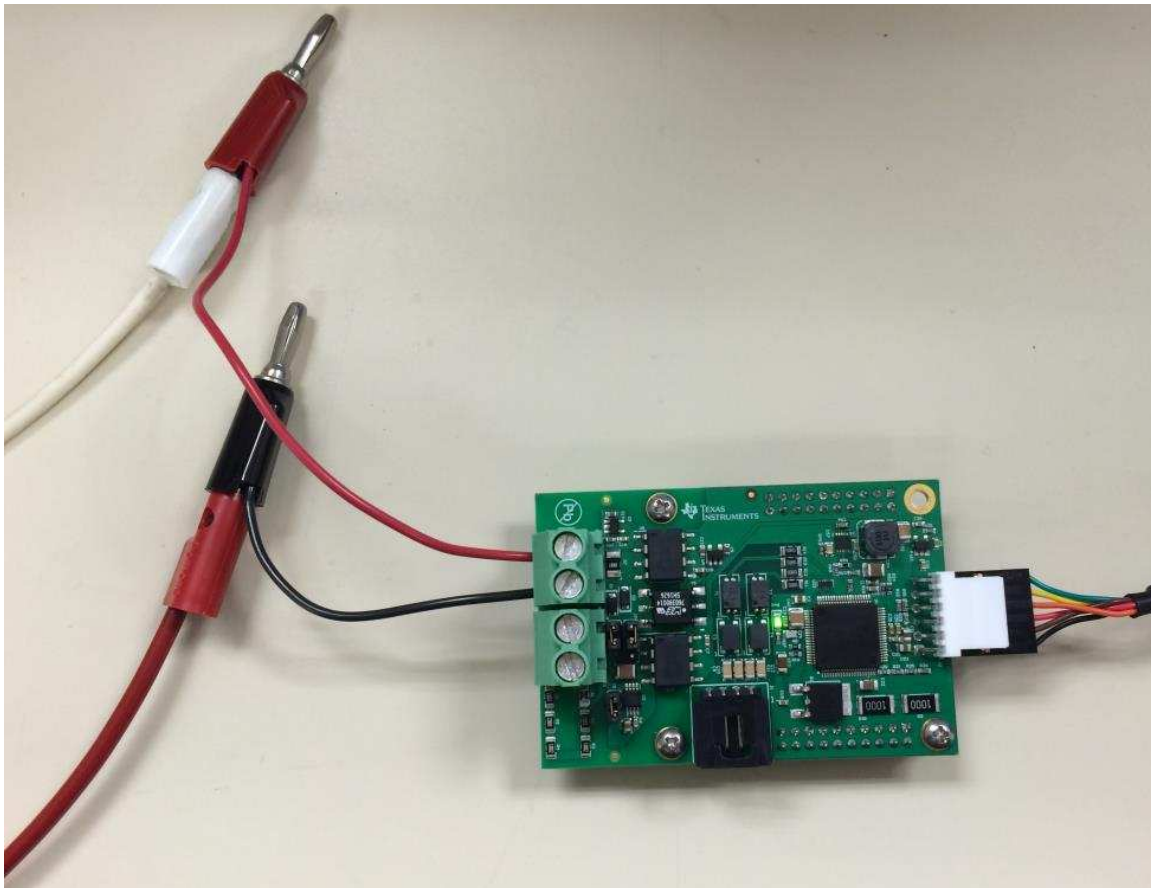


図 10. Isolated Current-Sense Measurement Setup

To configure the GUI, deselect all of the cell measurements and enable the AUX1 measurement. Move to the *Aux and I/O* tab, and click the *Poll Start* button to enable sampling of the AUX1 pin. With no current passing through the sense resistor, 2.54 V should be present at the AUX1 pin.

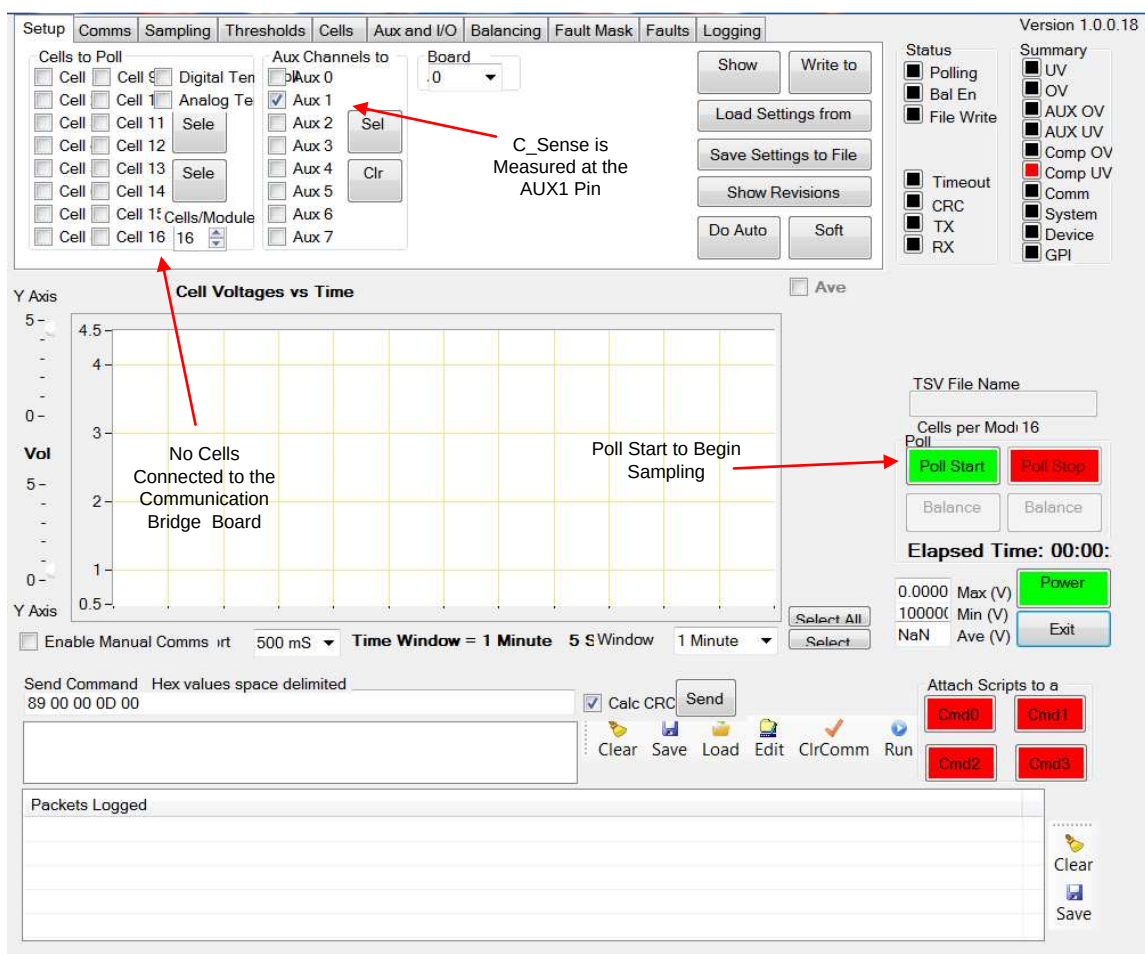


図 11. AUX1 Reading With No Current Passing Through a 10-mΩ Sense Resistor

Increasing the current drawn by the electronic load will increase the output voltage of the AMC1200B. Increasing the current to 2 A resulted in the AUX1 voltage to increase to 2.62 V with a 10-mΩ resistor, as seen in [Figure 12](#).

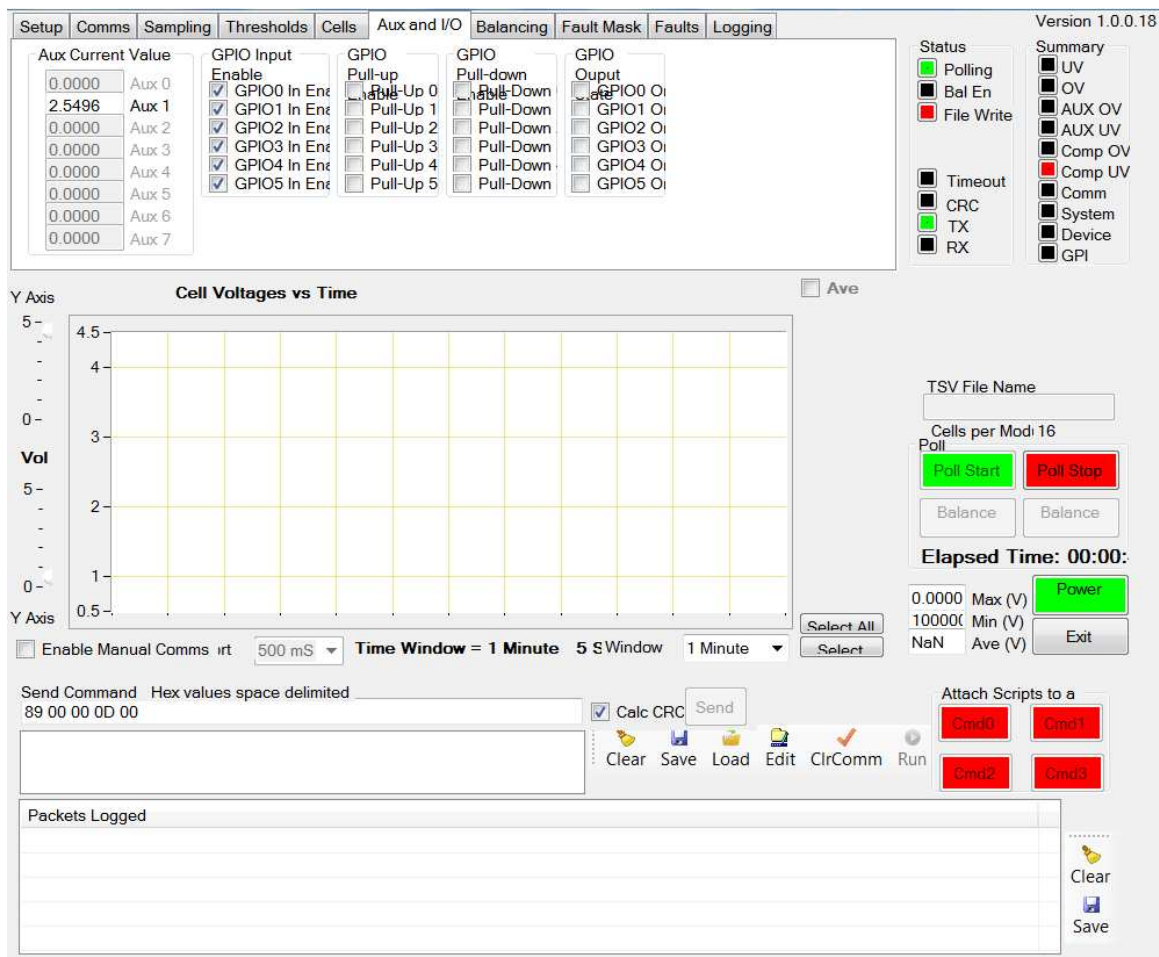


Figure 12. AUX1 Reading With 2 A Passing Through a 10-mΩ Resistor

The TIDA-01400 PCB was not laid out with high currents in mind, so there is insufficient copper to measure true pack voltages. It is recommended that the current being measured be less than 3 A if using the onboard shunt resistor. If larger currents are desired, it is suggested to remove the shunt resistor R7 and use an external shunt with parallel connections to header J4. When using the isolated current-sense measurement, it is important to size the shunt resistor so that the output of the AMC1200B remains less than 3.3 V; otherwise, damage to the MCU can occur.

表 2 summarizes some common shunt-resistor values and maximum currents without damaging a 3.3-V MCU.

表 2. Common Shunt Resistors and Maximum Current

EXTERNAL/ONBOARD	RESISTANCE	MAXIMUM CURRENT
Onboard	10 mΩ	18.75 A
Onboard	50 mΩ	3.75 A
Onboard'	100 mΩ	1.875 A
Onboard	500 mΩ	0.375 A
External	100 μΩ	1875 A
External	200 μΩ	937.5 A
External	500 μΩ	375 A
External	1 mΩ	187.5 A

4 Design Files

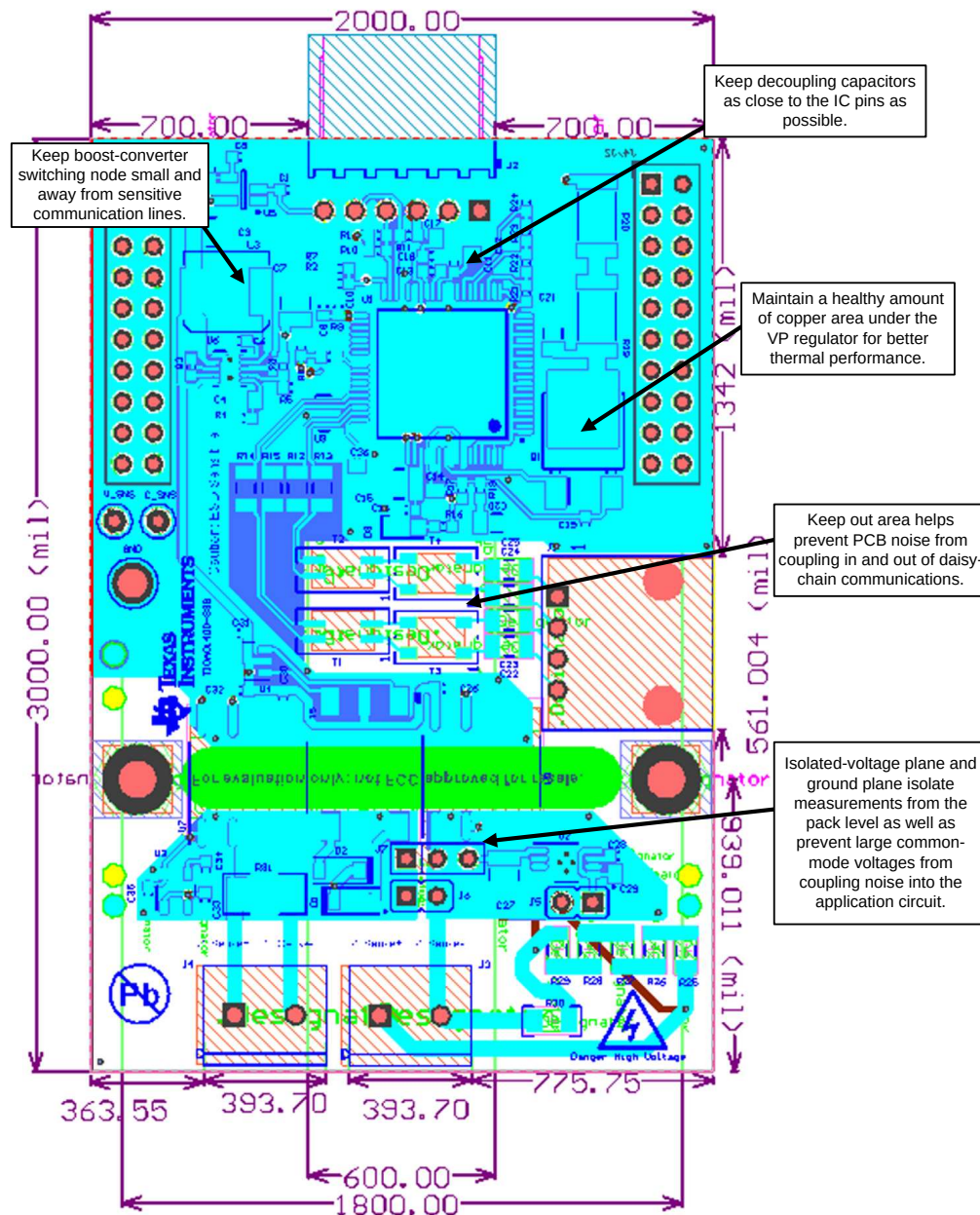
4.1 Schematics

To download the schematics, see the design files at [TIDA-01400](#).

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at [TIDA-01400](#).

4.3 PCB Layout Recommendations



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図 13. TIDA-01400 Layout Recommendations

4.3.1 Layout Prints

To download the layer plots, see the design files at [TIDA-01400](#).

4.4 Altium Project

To download the Altium project files, see the design files at [TIDA-01400](#).

4.5 Gerber Files

To download the Gerber files, see the design files at [TIDA-01400](#).

4.6 Assembly Drawings

To download the assembly drawings, see the design files at [TIDA-01400](#).

5 Related Documentation

1. Texas Instruments, [bq76PL455A 16-Cell Industrial Integrated Battery Monitor with Passive Cell Balancing](#), bq76PL455A Datasheet (SLUSCL0)
2. Texas Instruments, [bq76PL455EVM and GUI User Guide](#), bq76PL455A User's Guide (SLUUBA7)
3. Texas Instruments, [SN6501 Transformer Drive for Isolated Supplies](#), SN6501 Datasheet (SLLSEA0)
4. Texas Instruments, [TPS61093 Low-Input Boost Converter With Integrated Power Diode and Input/Output Isolation](#), TPS61093 Datasheet (SLVS992)
5. Texas Instruments, [AMC1200/B Fully-Differential Isolation Amplifier](#), AMC1200, AMC1200B Datasheet (SBAS542)
6. Texas Instruments, [bq76PL455A-Q1 Design Recommendations](#), Application Report (SLUA791)

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お客様は、自らのアプリケーションの設計において、ご自身が独自に分析、評価、判断を行う責任がお客様にあり、お客様のアプリケーション(および、お客様のアプリケーションに使用されるすべてのTI製品)の安全性、および該当するすべての規制、法、その他適用される要件への遵守を保証するすべての責任をお客様のみが負うことを理解し、合意するものとします。お客様は、自身のアプリケーションに関して、(1) 故障による危険な結果を予測し、(2) 障害とその結果を監視し、および、(3) 損害を引き起こす障害の可能性を減らし、適切な対策を行う目的で、安全策を開発し実装するために必要な、すべての技術を保持していることを表明するものとします。お客様は、TI製品を含むアプリケーションを使用または配布する前に、それらのアプリケーション、およびアプリケーションに使用されているTI製品の機能性を完全にテストすることに合意するものとします。TIは、特定のTIリソース用に発行されたドキュメントで明示的に記載されているもの以外のテストを実行していません。

お客様は、個別のTIリソースにつき、当該TIリソースに記載されているTI製品を含むアプリケーションの開発に関連する目的でのみ、使用、コピー、変更することが許可されています。明示的または黙示的を問わず、禁反言の法理その他どのような理由でも、他のTIの知的所有権に対するその他のライセンスは付与されません。また、TIまたは他のいかなる第三者のテクノロジーまたは知的所有権についても、いかなるライセンスも付与されるものではありません。付与されないものには、TI製品またはサービスが使用される組み合わせ、機械、プロセスに関連する特許権、著作権、回路配置利用権、その他の知的所有権が含まれますが、これらに限られません。第三者の製品やサービスに関する、またはそれらを参照する情報は、そのような製品またはサービスを利用するライセンスを構成するものではなく、それらに対する保証または推奨を意味するものでもありません。TIリソースを使用するため、第三者の特許または他の知的所有権に基づく第三者からのライセンス、あるいはTIの特許または他の知的所有権に基づくTIからのライセンスが必要な場合があります。

TIのリソースは、それに含まれるあらゆる欠陥も含めて、「現状のまま」提供されます。TIは、TIリソースまたはその仕様に関して、明示的か暗黙的にかかわらず、他のいかなる保証または表明も行いません。これには、正確性または完全性、権原、続発性の障害に関する保証、および商品性、特定目的への適合性、第三者の知的所有権の非侵害に対する黙示の保証が含まれますが、これらに限られません。

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お客様は、この注意事項の条件および条項に従わなかったために発生した、いかなる損害、コスト、損失、責任からも、TIおよびその代表者を完全に免責するものとします。

この注意事項はTIリソースに適用されます。特定の種類の資料、TI製品、およびサービスの使用および購入については、追加条項が適用されます。これには、半導体製品(<http://www.ti.com/sc/docs/stdterms.htm>)、評価モジュール、およびサンプル(<http://www.ti.com/sc/docs/sampterm.htm>)についてのTIの標準条項が含まれますが、これらに限られません。