# ACPL-339J/C87B/736J

## Dual IGBT Module EB1200-339J Evaluation Board

**Reference Manual**
**Version 2.1**

# Table of Contents

# Chapter 1: Introduction

The Broadcom® EB1200-339J evaluation board features dual-output isolated gate drive ACPL-339J optocouplers, used to drive Dual IGBT modules, and precision optically isolated ACPL-C87B amplifiers used for DC bus voltage and IGBT temperature measurements. The EB1200-339J can also be used in conjunction with ACPL-736J sigma-delta current sensing module to measure IGBT output current. The EB1200-339J, shown in Figure 1, is developed to support Broadcom customers during their first steps in designing inverter applications with ACPL-339J drivers. Properties of the board are described in the following chapters of this document. The contents of this document, which provide information related to the design, are intended to enable customers to copy and modify the design specifics according to their technical requirements for their in your own designs.

Components were selected considering lead-free reflow soldering. Design was tested as this documentation describes, but it is not qualified regarding operation in the whole operating ambient temperature range or lifetime. The board is subjected to functional testing only.

**Figure 1: Evaluation Gate Driver Board EB1200-339J and ACPL-736J Sigma Delta Current Sensing Module**

The EB1200-339J evaluation board is originally designed to be used with the Fuji Electric Dual XT IGBT module 2MBI600XNE120-50. With adequate adjustments regarding DESAT protection and gate resistors, the EB1200-339J can support other Dual modules rated up from 1200V/225A to 1200V/1000A with same pin assignment.

## 1.1 Design Features

EB1200-339J includes the following main features:

- Two isolated ACPL-339J gate drive optocouplers with following features:
  - DESAT (short circuit protection)
  - UVLO (undervoltage lockout protection)
  - Dual output drive for external NMOS and PMOS buffer
  - Active cross conduction prevention
  - Soft shutdown during fault
  - Isolated DESAT and UVLO fault feedback.
- Two ACPL-C87B optically isolated amplifiers for DC bus voltage and temperature measurement:
  - 0 to 2V nominal input range
  - 100 kHz bandwidth
  - 3V to 5.5V wide supply range for output side
  - 15 kV/μs common-mode transient immunity
- Electrically and mechanically suitable for Dual XT module 2MBI600XNE120-50 from Fuji Electric.
- With adjustment of the DESAT protection and gate resistors, the evaluation board supports the following modules:

  Fuji Electric Dual XT modules:
  - 2MBI225XNA120-50 (1200V/225A)
  - 2MBI300XNA120-50 (1200V/300A)
  - 2MBI450XNA120-50 (1200V/450A)
  - 2MBI600XNG120-50 (1200V/600A)
  - 2MBI800XNE120-50 (1200V/800A)
  - 2MBI1000XRNE120-50 (1200V/1000A)

  Infineon Dual IGBT modules:
  - FF225R12ME4 (1200V/225A)
  - FF300R12ME4 (1200V/300A)
  - FF450R12ME4 (1200V/450A)
  - FF600R12ME4 (1200V/600A)
- DC/DC power supply with current limit protection and thermal shutdown.
- Isolated SMPS for gate drivers.
- Access to FAULT output signals for protection and control development purposes.
- Access to PWM input signals.
- Access to current measurements via ACPL-736J sigma-delta current sensing module:
  - ±50 mV linear range (±80 mV full scale)
  - 10 MHz to 20 MHz external clock input range
  - 1-bit, second-order sigma-delta modulator
  - 16 bits resolution no missing codes
  - 80 dB typ SNR, 78 dB typ. SNDR
  - Sensing range of up to 1000A current together with a 0.05 mΩ shunt

## 1.2 Target Applications

Broadcom's ACPL-339J gate drive optocouplers, ACPL-C87B voltage sensors, and ACPL-736J current sensors target the following applications:

- Isolated IGBT/Power MOSFET gate drivers
- AC motor drives
- Renewable energy inverters
- Industrial inverters
- Switching power supplies

## 1.3 Warnings

Although the board itself is powered by low voltage, some features on the board operate at high voltages. Special care must be taken in order to avoid risk of injury and life endangering. While operating with the board, take into consideration following safety precautions:

- If the board is powered up, do not touch the board, especially exposed metal parts.
- Pay attention to the maximum ratings.
- Use of protection cover made of insulating materials is mandatory.
- If the board is used with a power module to drive continuous load, the power module must be mounted on a heat sink. The board might rise to high temperatures, and any contact with the human body must be avoided.
- Whenever a change in the test setup is done (for example, changing the probe position), turn off the power supply to avoid injuries and destruction of the board.
- The board itself does not provide dead-time generation. The recommended minimal dead time is 5 µs.

# Chapter 2: System Description

This chapter gives essential electrical and mechanical specifications of the EB1200-339J evaluation board.

## 2.1 Key Specifications

Absolute maximum ratings of EB1200-339J evaluation board are listed in Table 1. Note that this table contains only key parameters. Constraints from ACPL-339J, ACPL-C87B and ACPL-736J datas heets as well as specification of other key components must be considered when the boards are used.

**Table 1: Absolute Maximum Ratings**

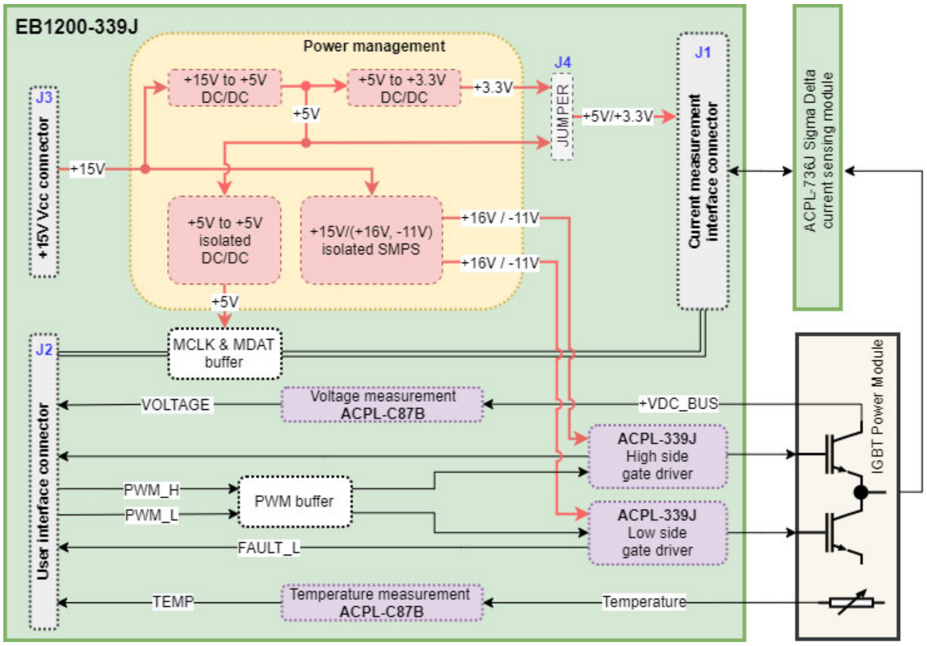
| Parameter | Values | | | Unit | Note |
|---|---|---|---|---|---|
| | Min. | Typ. | Max. | | |
| $V_{CC}$ Input Voltage | 13 | 15 | 18 | V | External DC input power supply for digital circuitry. Limited by SMPS range for gate drivers. |
| PWM Logic Input Level | 0 | 3.3 | 5 | V | External PWM inputs for gate drivers. |
| Fault Logic Output Level | 0 | — | 5 | V | Logic output signal, refer to the ACPL-339J data sheet. |
| UVLO Output Logic Level | 0 | — | 5 | V | Logic output signal, refer to the ACPL-339J data sheet. |
| MCLK and MDAT Input Logic Level | 0 | — | 5 | V | Clock and Data logic input signals for current measurement, refer to the ACPL-736J data sheet. |
| Buffered MCLK and MDAT Output Logic Level | 0 | — | 5 | V | Buffered clock and data logic output signals for current measurement refer to the ACPL-736J data sheet. |
| Voltage Measurement | 0 | — | 5 | V | Single ended analog output signal |
| Temperature Measurement | 0 | — | 5 | V | Single ended analog output signal |

## 2.2 Functional Block Diagram

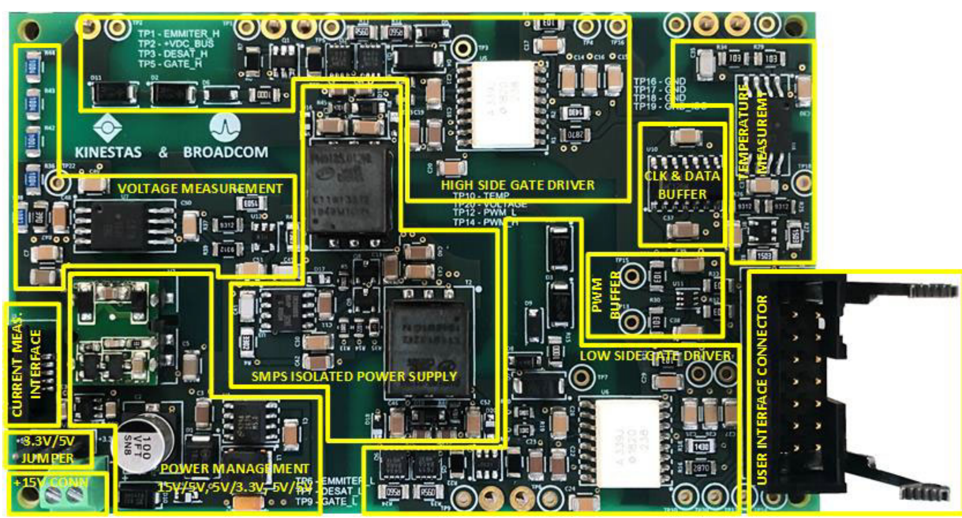
The functional block diagram and disposition of the functional blocks of the EB1200-339J gate driver evaluation board are shown in Figure 2 and Figure 3. The block diagram shows several different functional blocks:

- Power management:
  - +15V/+5V DC/DC regulator
  - +5V/+5V isolated DC/DC regulator
  - +5V to +3.3V LDO
- +16V/–11V isolated SMPS with two outputs (one for high side driver and one for low side driver)
- High and low side ACPL-339J gate drivers with circuitry
- Voltage and temperature measurements with two ACPL-C87B
- Buffered clock and data signals that interface with current measurement
- User interface connector
- +15V Vcc power supply connector and
- ACPL-736J current sensing module interface connector.

### Figure 2: Functional Block Diagram of EB1200-339J




### Figure 3: Functional Blocks Disposition of the EB1200-339J



## 2.3 Pin Assignment

The pin assignments for all connectors on the EB1200-339J are shown in Table 2 to Table 5.

**Table 2: Pin Assignment of Connector J1 (Interface to ACPL-736J Current Sensing Module)**

| Pin | Label | Function | Direction |
|---|---|---|---|
| 1 | +5V | +5V power supply fed directly to current measurement. | Output |
| 2 | +5V/+3V3 | Either +5V or +3.3V chosen by setting the jumper on J4. | Output |
| 3 | MCLK_CSB | Clock signal for current measurement. | Input |
| 4 | MDAT_CSB | Data signal for current measurement. | Input |
| 5 | GND | Ground. | Bidirectional |

**Table 3: Pin Assignment of Connector J2 (User Interface Connector)**

| Pin | Label | Function | Direction |
|---|---|---|---|
| 1 | GND | Ground. | Bidirectional |
| 2 | MCLK | Buffered clock signal for current measurement. | Output |
| 3 | GND | Ground. | Bidirectional |
| 4 | MDAT | Buffered data signal for current measurement. | Output |
| 5 | GND | Ground. | Bidirectional |
| 6 | TEMP | Single ended temperature measurement signal. | Output |
| 7 | VOLTAGE | Single ended DC Bus voltage measurement signal. | Output |
| 8 | GND | Ground. | Bidirectional |
| 9 | FAULT_L | DESAT or UVLO fault signal from low side driver. | Output |
| 10 | FAULT_H | DESAT or UVLO fault signal from high side driver. | Output |
| 11 | GND | Ground. | Bidirectional |
| 12 | PWM_L | PWM signal for low side driver. | Input |
| 13 | PWM_H | PWM signal for high side driver. | Input |
| 14 | GND | Ground. | Bidirectional |

**Table 4: Pin Assignment of Connector J3 (Power Supply Connector)**

| Pin | Label | Function | Direction |
|---|---|---|---|
| 1 | GND | Ground. | Bidirectional |
| 2 | +V_SUPPLY | Power supply | Input |

**Table 5: Pin Assignment of Pin Header Connector J4 (Power Supply Selection Jumper for Current Measurement Board)**

| Pin | Label | Function |
|---|---|---|
| 1 | +5V | Jumper position 1; +5V for ACPL-736J current sensing module. |
| 2 | +5V/+3V3 | Jumper common point for current measurement power supply. |
| 3 | +3V3 | Jumper position 2; +3.3V for ACPL-736J current sensing module. |

## 2.4 Mechanical Data

Table 6 provides the mechanical data of the evaluation board.

**Table 6: Mechanical Characteristics of EB1200-339J Evaluation Board**

| Description | Value |
|---|---|
| Number of Layers | 4 |
| PCB Copper Thickness | 35 µm to all layers |
| PCB Insulating Material | FR4 |
| Board Weight | 50g |
| Board Length | 99.6 mm |
| Board Width | 62 mm |
| Board Height | 14 mm |
| PCB Thickness | 1.55 mm |

# Chapter 3: Circuit Description

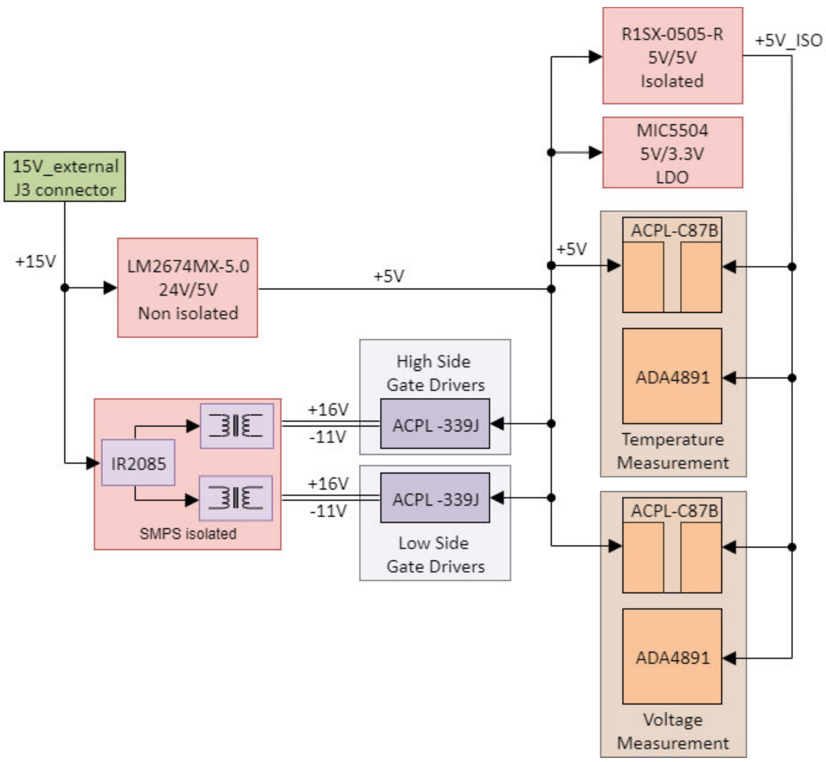
This chapter gives an in-depth insight of EB1200-339J gate driver evaluation board and ACPL-736J current sensing module features.

## 3.1 Power Management

Figure 4 shows an auxiliary power management block diagram of the EB1200-339J. The evaluation board is supplied from external +15V source.

The EB1200-339J is equipped with an SM power supply that provides two isolated dual outputs of +16V and –11V for each gate driver powering the high-voltage side. This circuitry is shown in Figure 5. SMPS is based on the IR2085 self-oscillating half bridge gate driver and two transformers with 1:2 ratio.

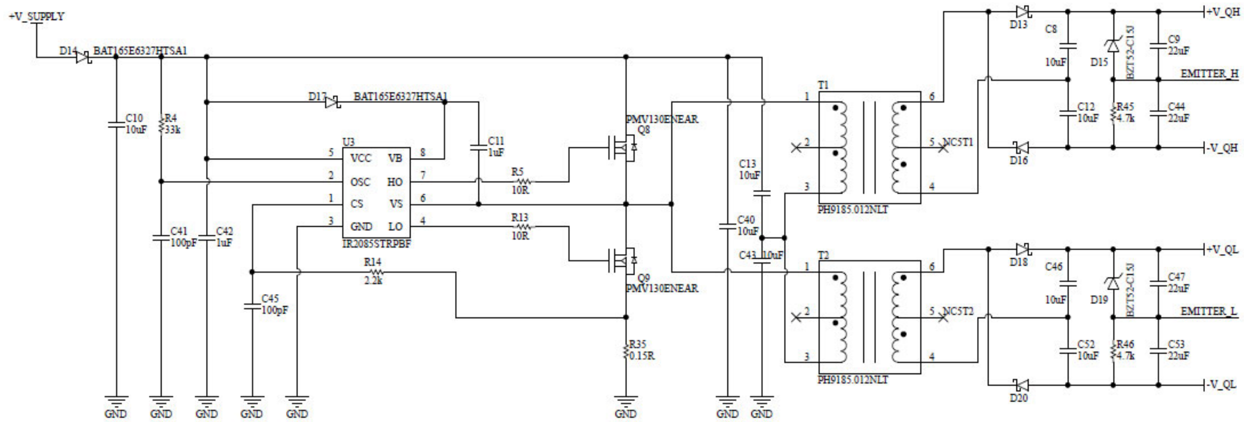
**Figure 4: Power Management Block Diagram**




The main 15V/5V power supply is realized with LM2674 DC-DC switching regulator, as shown in Figure 6. A +5V output is used to supply the low voltage side of the ACPL-339J gate drivers and two ACPL-C87B voltage sensors. The LM2674, a high efficiency step down voltage regulator with fixed output voltage of 5V, is capable of driving a 500 mA load while preserving excellent line and load regulation. A +5V voltage reference generated by the LM2674 is used to supply all ICs on the board and could be selected by jumper to be used as a power supply for the ACPL-736J current sensing module.

An isolated 5V/5V voltage regulator R1SX-0505-R provides isolated 5V for the ACPL-C87B voltage sensors high-voltage side, as shown in Figure 7.

**Figure 5: Isolated SMPS for Gate Driver Output Stage**




The EB1200-339J is connected to the ACPL-736J current sensing module through FPC 5 pins J1 connector (marked as current measurement interface in Figure 2). Current can be measured using a 0.05-mΩ shunt at the IGBT power module out terminals with Broadcom's isolated sigma-delta modulator, ACPL-736J. As the low voltage side of the ACPL-736J supports power supply of either 5V or 3.3V, the EB1200-339J enables the voltage level selection via jumper. For this purpose, the EB1200-339J consists of the high-performance LDO 5V/3.3V, shown in Figure 8, that enables alternative powering of the ACPL-736J current sensing module with 3.3V.

**Figure 6: +15V/+5V DC/DC Switching Regulator Circuit**

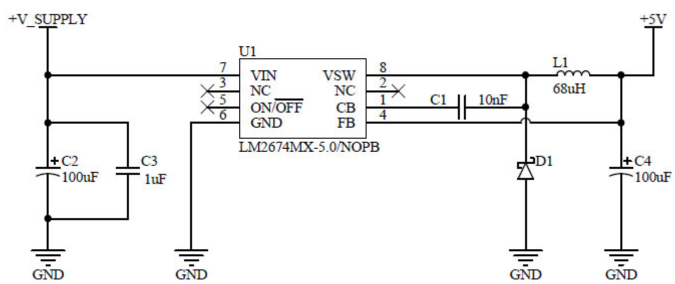



**Figure 7: +5V to +5V_ISO Unregulated Isolated DC/DC Converter**

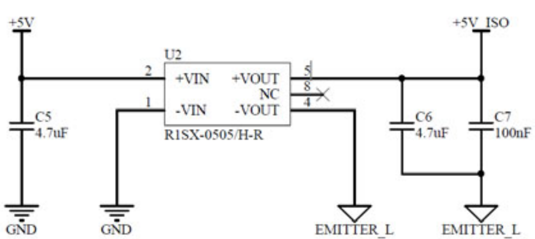
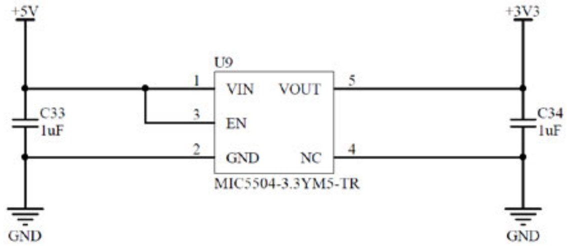


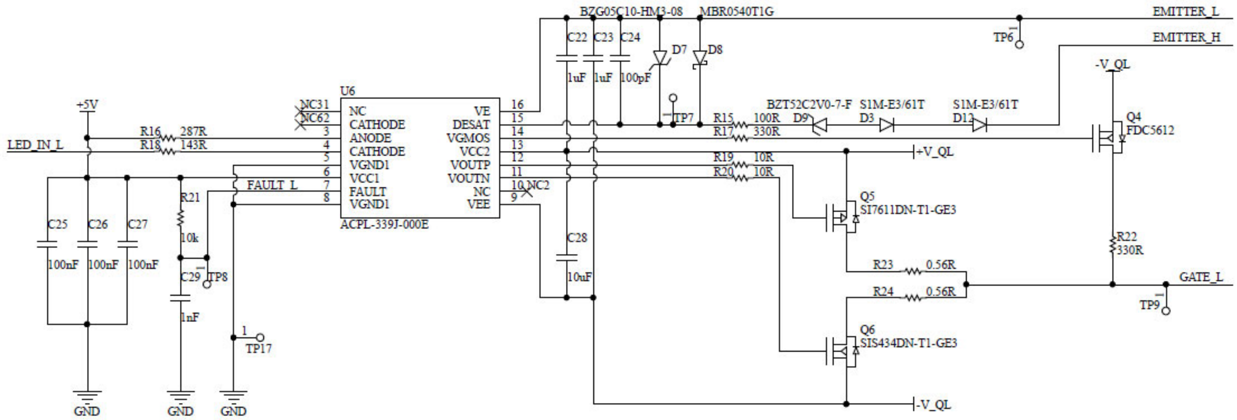
**Figure 8: +5V/+3V3 LDO**




# 3.2 Gate Driver Circuit

This section deals with gate driver circuitry on EB1200-339J. Description of related features and functionalities is presented in the following paragraphs. Gate drive circuitry is shown in Figure 9.

**Figure 9: ACPL-339J IGBT Gate Driver Circuitry**




Designed to support a MOSFET buffer of various current ratings, ACPL-339J supports different system power ratings using one platform by interchanging the MOSFET buffers and power IGBT/MOSFET switches. This concept maximizes gate drive scalability for motor control and power conversion applications ranging from low to high power ratings. This driver contains one LED, optically coupled to an integrated circuit with two power output stages with active timing control to prevent cross conduction at an external MOSFET buffer. Other features encompass UVLO and DESAT protection features as well as soft IGBT turn-off at fault.

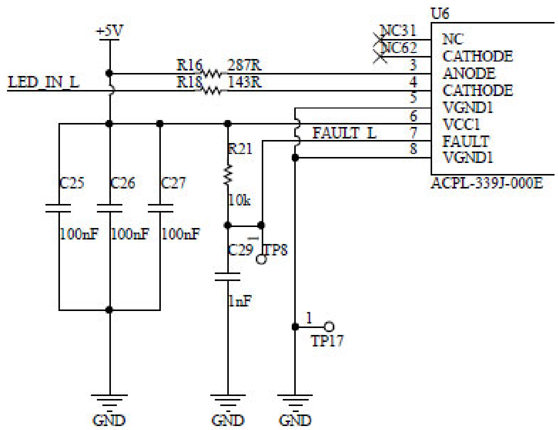
## 3.2.1 Gate Driver Circuit: Low-Voltage Side

The low voltage side of the gate drive circuitry shown in Figure 10 contains power supply for the ACPL-339J, LED input and output and fault signal.

Two current setting resistors are placed on pins 3 and 4 to balance the common mode impedances at the LED's anode and cathode. This helps to equalize the common mode voltage change at the anode and cathode. Resistors values are selected as defined in the data sheet of the gate driver.

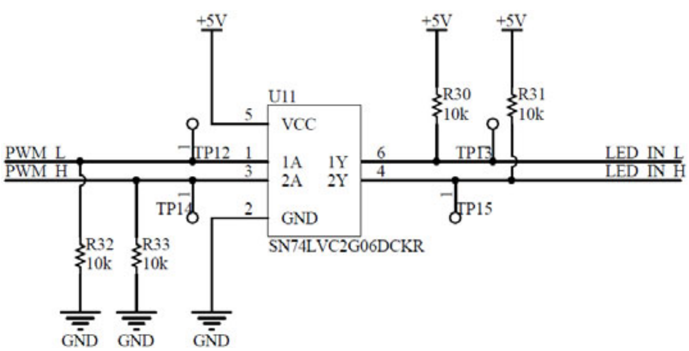
While the input LED is directly polarized and there is no fault, VOUTP pin of the ACPL-339J will set high, turning on the buffer MOSFET, thus feeding +16V to the gate of the IGBT. The ANODE pin is pulled high via resistor R16. The input signal LED_IN_L is connected to one of the CATHODE pins (in this case pin 3). When the input LED_IN_L signal is low, the LED is directly polarized and IGBT is turned on. In the case where the input signal LED_IN_L is high, the voltage across the LED and two resistors is low; therefore, the LED is not conducting and the IGBT is in off state.

**Figure 10: Gate Driver Circuit: Low-Voltage Side**




External PWM signals that propagate through the user interface connector are buffered, as shown in Figure 11. The buffer features an open drain output. Inputs of the buffer are pulled down while outputs of the buffer are pulled high to ensure that the IGBT module is off in case the input PWM signals are in high impedance states.

**Figure 11: PWM Buffer**




In the case where DESAT or UVLO conditions are met, the FAULT output is high, and the driver does not allow IGBT turn on.

## 3.2.2 Gate Driver Circuit: High-Voltage Side

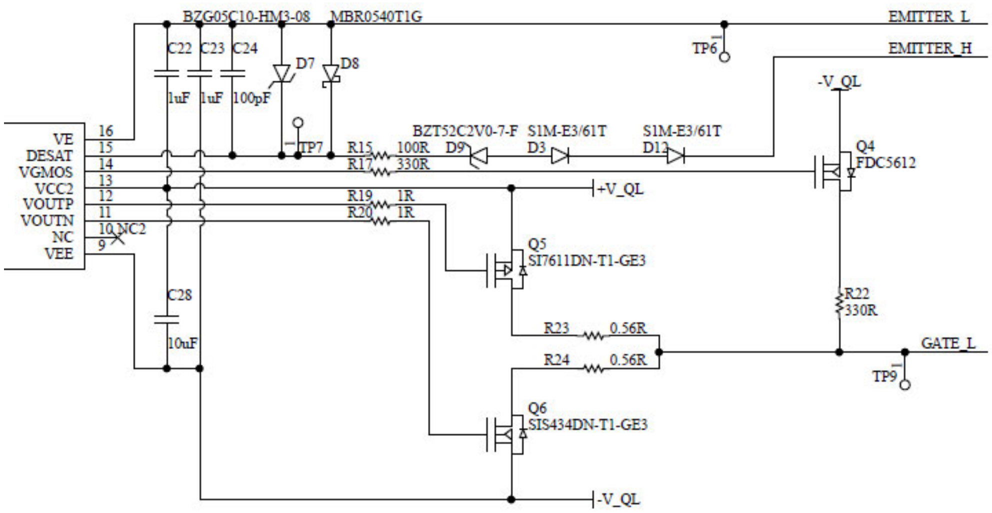
The secondary side of the gate drive circuitry is shown in Figure 12. It includes DESAT and UVLO protection related circuits, MOSFET buffers, and soft turn-off in case of fault.

MOSFET buffers are connected via 1Ω resistors to VOUTP and VOUTN pins. When VOUTP is high, +16V is connected to the IGBT gate through a 0.56Ω resistor. When VOUTN is high, IGBT gate is connected through the resistor of the same value to –11V. These voltages are referred to the emitter of the respective IGBT.

The IGBT switching time is determined by gate charging and discharging. Higher peak gate current decreases turn-on and turn-off time subsequently reducing switching losses. Gate current is controlled by the gate resistors. In order to do appropriate selection of the gate resistors, several criteria must be fulfilled.

First is the limit of the gate peak current. This peak must be kept below the maximum allowed values for the buffer MOSFETs. The buffer MOSFET internal RDSON must be considered when calculating the ideal value for the gate resistor. The equation for the gate resistor calculation is given in the ACPL-339J data sheet.

**Figure 12: Gate Driver Circuit: High-Voltage Side**




$$R_G \geq \frac{V_{CC} - V_{EE}}{I_{O\,(PEAK)}} - R_{DSON}$$

Note that $R_{DSON}$ can be different for high-side and low-side power switch; hence, calculations for both are necessary. Buffer power MOSFETS were chosen according to the ACPL-339J data sheet.

The next step in choosing the right gate resistor is checking the power dissipation of ACPL-339J gate driver. If the power dissipation is too high, resistance of the gate resistor should be increased. For detailed instruction on choosing the gate resistor, refer to the ACPL-339J data sheet.

The final step in the turn-off gate resistor selection is ensuring that during turn-off transient, at the maximum allowed collector current, the IGBT collector-emitter voltage does not exceed the blocking voltage of the IGBT device. The final criteria for the turn-on gate resistor is the maximum collector current peak, related to the reverse recovery of the opposite freewheeling diode. This peak must not exceed double value of the nominal collector current.

In order to ensure the constraints described, the EB1200-339J comes with 0.56Ω gate resistors both for positive and negative gating. In addition, the evaluation board is designed to enable Broadcom customers to evaluate switching characteristics of the semiconductors by changing or combining turn-on/off resistors.

**Table 7: Recommended $R_G$ for Different Ratings of Dual IGBT Modules**

| Fuji Electric Dual XT Module | Recommend $R_G$ (R23/R24) |
|---|---|
| 2MBI225XNA120-50 (1200V/225A) | 0.82Ω |
| 2MBI300XNA120-50 (1200V/300A) | 1Ω |
| 2MBI450XNA120-50 (1200V/450A) | 0.68Ω |
| 2MBI600XNG120-50 (1200V/600A) | 0.56Ω |
| 2MBI800XNE120-50 (1200V/800A) | 0.5Ω |
| 2MBI1000XRNE120-50 (1200V/1000A) | 0.5Ω |
| **Infineon Dual IGBT Module** | **Recommend $R_G$ (R23/R24)** |
| FF225R12ME4 (1200V/225A) | 1Ω |
| FF300R12ME4 (1200V/300A) | 1Ω |
| FF450R12ME4 (1200V/450A) | 1Ω |
| FF600R12ME4 (1200V/600A) | 1.2Ω |

## 3.2.3 Protection Features

VOUTP and VOUTN will remain functional until DESAT or UVLO protection features are activated.

**DESAT**:

The DESAT pin monitors the IGBT collector-emitter voltage. DESAT fault detection circuitry must remain disabled for a short time period following the turn-on of the IGBT to allow the collector voltage to settle down and fall below the DESAT threshold. This time period, called the DESAT blanking time, is controlled by the internal DESAT current source, the DESAT voltage threshold, and the external DESAT capacitor. The nominal blanking time is calculated using the following equation:

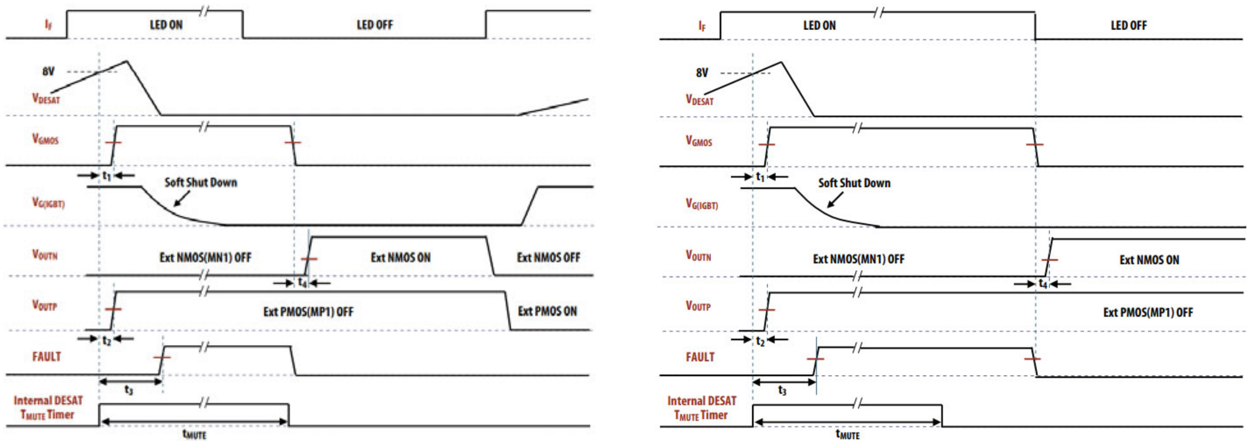
$$T_{BLANK} = \frac{C_{BLANK} \times V_{DESAT}}{I_{CHG}}$$

where $C_{BLANK}$ is external capacitance, $V_{DESAT}$ is fault threshold voltage, and $I_{CHG}$ is DESAT charge current. Nominal blanking time also represents the longest time it will take for the driver to respond to DESAT fault condition. Once the DESAT fault is detected and blanking time has passed both VOUTP and VOUTN will turn off their respective buffer MOSFETs and VGMOS will turn on an external pull-down transistor for soft shutdown of the IGBT to commence. Soft shutdown prevents fast changes in the collector current that can cause voltage spikes due to lead and wire inductance and thus prevent the damage of the device. Decay rate corresponds to the RC constant of external resistor and IGBT gate capacitance.

When DESAT conditions are met, the internal feedback channel is activated, which brings the FAULT output from low to high. Once the fault is detected, VOUTP and VOUTN will be muted for $T_{MUTE}$ time. All input LED signals will be ignored during this period to allow the driver to completely soft shut down the IGBT. Mute time lasts typically 1 ms after which fault auto-reset occurs.

In order to correctly adjust DESAT threshold voltage, careful consideration of DESAT diode(s) should be conducted. Its function is to conduct forward current in order to allow IGBT's saturated collector-emitter voltage sensing when IGBT is on and to block high voltages when IGBT is off. Nominal threshold value is 8V – $V_F$, where $V_F$ is DESAT diode forward voltage drop. If desired, this threshold voltage can be further decreased by adding multiple DESAT diodes or Zener diode. Adding more diodes in series has benefits in their lower voltage rating. If a Zener diode is used, then the nominal threshold voltage value is 8V – $V_F$ – $V_D$.

**Figure 13: DESAT Fault State with LED Turn-Off: (a) Before Mute Timeout, (b) After Mute Timeout**




(a) (b)

In the current design, threshold voltage is set to be 3.8V. This means that the DESAT protection will react after the IGBT collector current reaches approximately 2400A for the selected IGBT.

The freewheeling of the antiparallel diodes connected across the IGBT can have large instantaneous forward voltage transients. This can result in a large negative voltage spike on the DESAT pin, which will draw substantial current from the driver if protection is not used. Limiting this current is done via 100Ω resistor placed in series with DESAT diodes.

Negative voltage spikes typically generated by inductive loads or reverse recovery spikes of the IGBT/MOSFET free-wheeling diodes can bring DESAT pin voltage above the threshold, thus generating false fault signal. In order to prevent this, Zener and Schottky diodes are placed across the DESAT and $V_E$ pins. The Zener diode protects the DESAT pin from positive high transient voltage and the Schottky diode prevents forward biasing of the substrate diode of the gate driver optocoupler.

**UVLO**:

Insufficient gate voltage on IGBT during turn-on phase can increase voltage drop across IGBT. This results in large power loss and IGBT damage due to high heat dissipation. The ACPL-339J monitors the output power supply constantly. If the power supply voltage is lower than UVLO threshold, driver output will turn-off in order to protect the IGBT from low voltage bias. UVLO protection precedes DESAT protection.

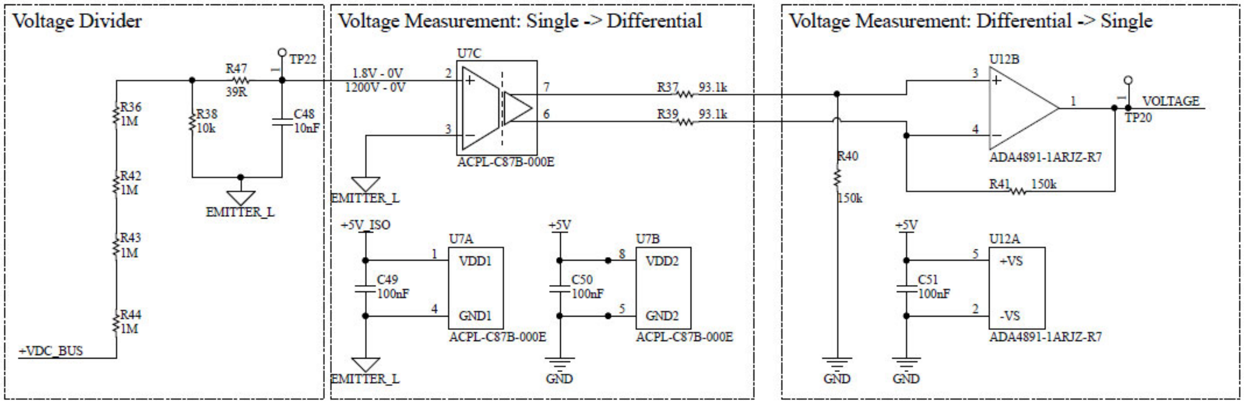
## 3.3 Measurements

The EB1200-339J is featured with DC bus voltage measurements, IGBT module temperature measurement, and current measurement interface to support the ACPL-736J current sensing module. Available measurements are described in the following text.

### 3.3.1 Isolated DC Bus Voltage Measurement

Isolated DC bus voltage measurement is realized using ACPL-C87B optically isolated high precision voltage sensor. Figure 14 shows voltage measurement circuitry.

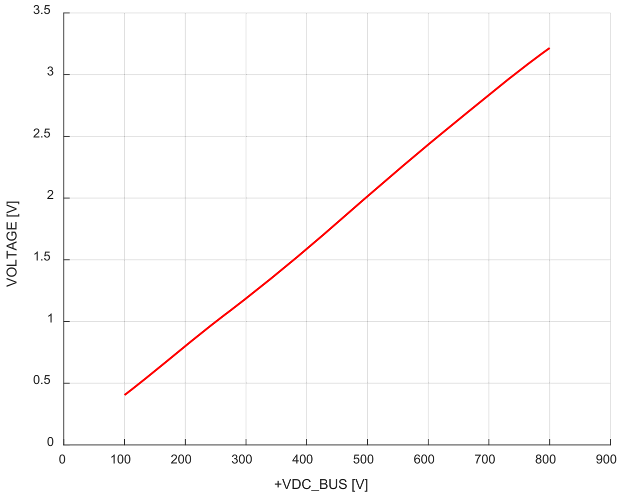
**Figure 14: Isolated DC Bus Voltage Measurement**




The DC bus voltage is brought to the voltage divider, which scales 1200V to 1.8V. In this design, four 1 MΩ resistors and one 10 kΩ resistor are used to form the voltage divider. Note that these resistors need to have a low tolerance due to required precision. Resistor R47 and capacitor C48 are added for anti-aliasing.

The obtained signal is then transformed into a differential signal on the secondary side of the ACPL-C87B. In order to make the measurement more user friendly, this differential signal is transformed back to a single-ended signal using a ADA4891 low-cost high-speed amplifier. Output of the circuitry is a 0V to 5V analog signal, which is a linear representation of DC bus voltage ranging from 0V to 1200V. The typical DC bus voltage response of the measurement circuit is shown in Figure 15.

**Figure 15: Typical Voltage Measurement Characteristic**




In case of using the proposed single ended configuration for the end application design, it is strongly recommended to add additional filter across the operation amplifier in order to attenuate high frequency spikes.

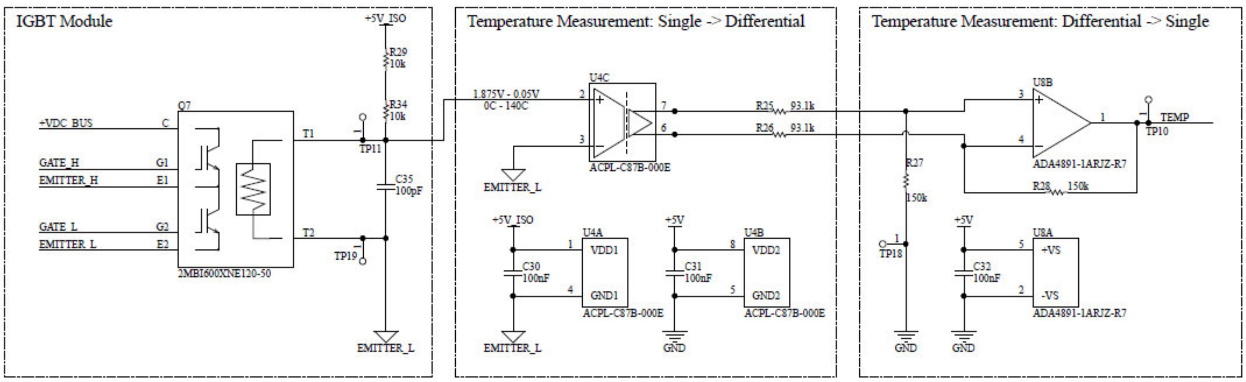
## 3.3.2 Isolated Temperature Measurement

Isolated temperature measurement is designed using the same isolated voltage sensor, ACPL-C87B. As can be seen in Figure 16, a similar configuration that is used for the DC link voltage measurement is also used for the temperature measurement.

The Dual XT IGBT module 2MBI600XNE120-50 possesses an internal NTC thermistor with values that range from 15 kΩ at 0°C to 200Ω at 140°C. Isolated 5V is fed through this thermistor with added 20 kΩ in series. This forms a voltage divider; therefore 0°C to 140°C is represented by 1.875V to 0.05V.

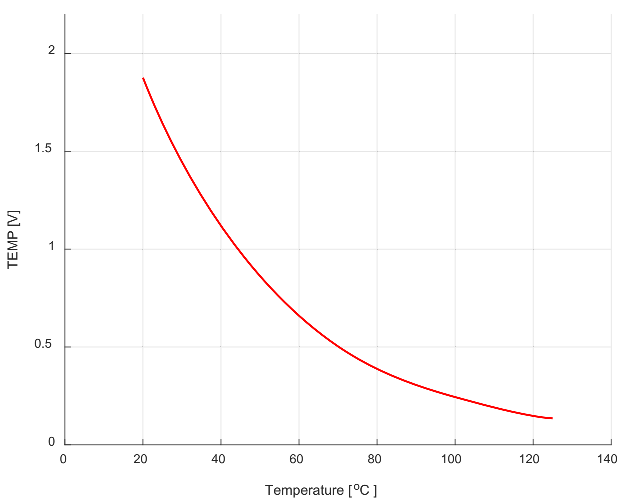
The rest of the temperature measurement circuitry is the same as in DC bus voltage measurement. At the output, the temperature range of 0°C to 140°C is scaled to 5V to 0.1V

**Figure 16: Isolated Temperature Measurement**




The typical temperature response of the measurement circuit is shown in Figure 17. Note that output voltage range can be adjusted by changing the value of the feedback resistor R28 as well as resistors R25 and R26 in the amplifier circuit.

**Figure 17: Typical Temperature Measurement Characteristic**



### 3.3.3 IGBT Output Current Measurement

The IGBT output current measurement is done using the ACPL-736J current sensing module. The IGBT current from the IGBT's OUT terminal is measured using a 0.05 mΩ shunt resistor (KOA HS-50U-2). Depending on the IGBT modules' ratings, the output current will range from 225A to 1000A. This will give a sense voltage of 11.25 mV to 50 mV, which is within the ±50 mV linear range of the ACPL-736J. The shunt resistor is connected to the board via S1 and S2 terminals with M3 screws.

The current sensing module's H1 connector is connected to the EB1200-339J's J1 connector using a 5-pole FPC cable. The EB1200-339J will provide 5VCC and VDD2 to power up the board and ACPL-736J respectively. The U2 (pSemi PE33100) transformer driver will switch the transformer T1 (Wurth 750344162) to provide isolated supply, VDD1 to secondary side of ACPL-736J. U3 provides a 20 MHz external CLK to the ACPL-736J and the CLK frequency can be adjusted by the resistor, R4.

**Figure 18: Functional Blocks Disposition of the ACPL-736J Current Sensing Module**

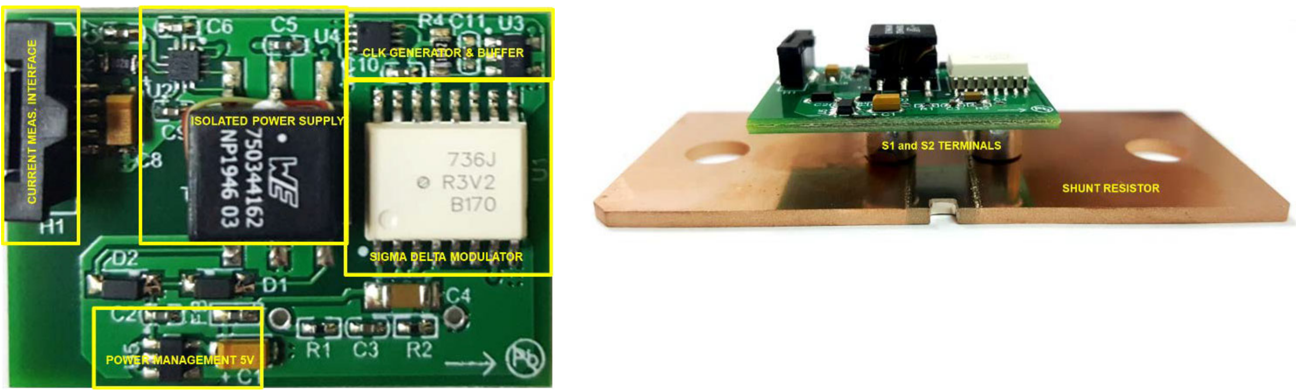
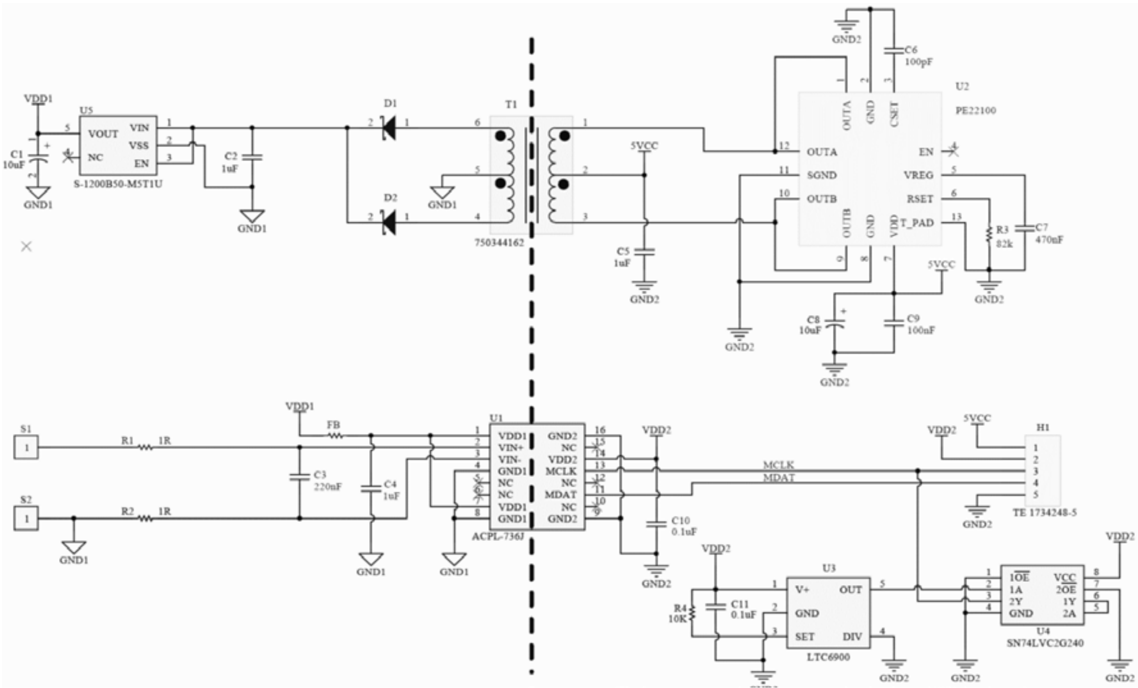


**Figure 19: Schematic of the ACPL-736J Current Sensing Module**




The ACPL-736J is a 1-bit, second-order sigma-delta modulator that converts an analog input signal into a high-speed data stream with galvanic isolation based on optical coupling technology. The ACPL-736J operates from a 3.3V or 5V power supply with dynamic range of 80 dB.

The analog input is continuously sampled by means of sigma-delta oversampling using the external clock, coupled across the isolation barrier, which allows synchronous operation with any digital controller. The signal information is contained in the modulator data, as a density of ones with data rate up to 20 MHz, and the data are encoded and transmitted across the isolation boundary where they are recovered and decoded into high-speed data stream of digital ones and zeros. The original signal information can be reconstructed with a digital filter.

Combined with superior optical coupling technology, the modulator delivers high noise margins and excellent immunity against isolation-mode transients. With 0.5 mm minimum distance through insulation (DTI), the ACPL-736J provides reliable double protection and high working insulation voltage, which is suitable for fail-safe designs.

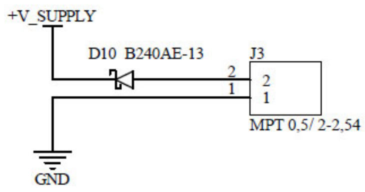
# 3.4 Connectors

Connectors of the EB1200-339J are described in the following sections.

## 3.4.1 Vcc +15V Connector

The power supply connector +15V is a standard two-position PCB terminal block. Figure 20 shows the connector schematic.

**Figure 20: +15V Power Supply Connector**

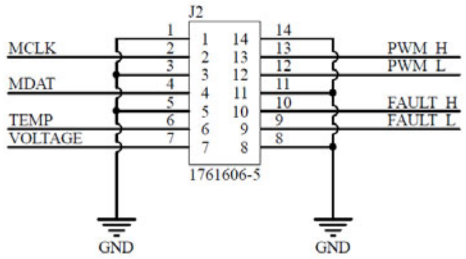



For the reversed voltage protection, the Schottky diode is placed in series with the main power supply.

## 3.4.2 User Interface Connector

User interface header connector serves as an interface between the microcontroller or PWM signal source and the EB1200-339J evaluation board. Figure 21 shows the disposition of signals across this connector.

**Figure 21: User Interface Connector**




Besides providing input for the PWM signals, the user interface connector J2 provides output for the fault signals, voltage and temperature measurements, as well as buffered MCLK and MDAT signals from the ACPL-736J current sensing module.

## 3.4.3 Current Measurement Interface Connector

The EB1200-339J evaluation board integrates a double-buffered MCLK and MDATA input that serves as the interface to the external current measurement board. The two signals from the ACPL-736J current sensing module are brought to the EB1200-339J using the FPC connector. They are then routed to the buffer, and subsequently to the user via the user interface connector. Note that these signal routes need to have the same length; therefore length matching must be applied in the layout. Figure 22 shows the buffer configuration, and Figure 23 shows the current measurement interface connector.

**Figure 22: MCLK and MDAT Buffer Configuration**

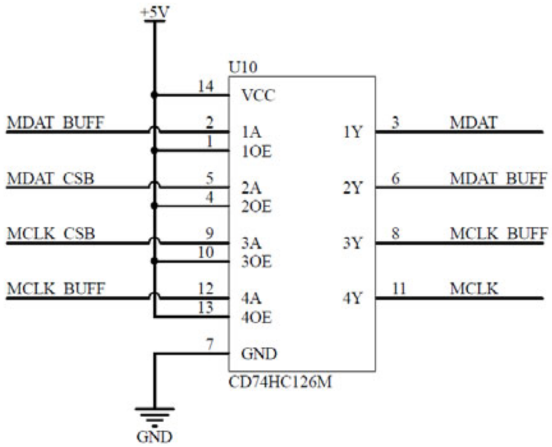
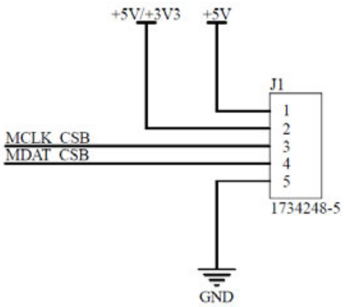



**Figure 23: Current Measurement Interface Connector**




The EB1200-339J gives the user a possibility to select voltage reference to be used for powering the external current measurement board. Available voltage levels are 5V and 3.3V, which can be chosen by correct adjusting of the jumper J4.

# Chapter 4: Setup in Use

**WARNING!** The EB1200-339J gate driver evaluation board is designed to work with voltages up to 800V and thus requires that all safety precautions and national accident prevention rules be undertaken. Installation and use of the board should be reserved for the skilled technical personnel. There is a danger of serious injury and damage of property if the board is not properly used or installed. It is strongly recommended that a system aimed to supply the evaluation board is equipped with control and protection devices, in agreement with applicable safety standards.

**ATTENTION:** Signals dedicated for high-side driver and low-side driver must have proper dead time. The board itself does not provide dead time generation. The recommended minimal dead time value is 5 µs.

## 4.1 Installation of EB1200-339J

Before evaluating the board, the following installation steps must be considered and observed:

1. Before any installation, make a visual inspection of the board to make sure it contains all components assembled, except the Dual IGBT module. See Section 6.3, BOM, for the list of components. The EB1200-339J, by default, does not contain an assembled Dual IGBT module to avoid damage to the module and the evaluation board during transport, as well as to provide the customer an option to use other modules with the same footprint.
2. Assemble the Dual IGBT module.
3. Ensure that short circuit protection feature (DESAT) is well adjusted. Depending on the IGBT module assembled, readjustment of the DESAT Zener diode should be considered. For the safety reasons, select the DESAT Zener diode with clamp voltage level high enough to enable fast short circuit detection. For the details regarding the DESAT Zener diode adjustment, refer to ACPL-339J data sheet.
4. Ground the external DC_BUS. Connect negative pole of the DC_BUS to the protective earth potential (PE).
5. Connect the user interface connector. The PWM signals, as well as the ACPL-339J output fault signals, can be connected to any control board with 5V or 3.3V logic.
6. If using the EB1200-339J with the ACPL-736J current sensing module, connect the current measurement interface connector to the ACPL-736J current sensing module with standard 5 pins FPC flat cable.
7. With the available jumper select the desired voltage reference for current measurement board. Available references are 5V and 3.3V.
8. Connect a 15V external power supply. The EB1200-339J requests a 15V external power supply to enable 5V and 3.3V digital operations and +16V and –11V gate driver high voltage side power supply. Although the polarity is marked, the board is reverse protected at the $V_{CC}$ terminal of +15V external supply.

## 4.2 Evaluation of EB1200-339J

The EB1200-339J enables users to evaluate the following items:

- ACPL-339J driver features
- ACPL-C87B precision voltage sensor features
- ACPL-736J current sensor features
- Switching characteristics of the IGBT module
- Half-bridge inverter basic features

In order to evaluate semiconductor switching characteristics with the EB1200-339J, perform a double pulse test and measure the transients related to the semiconductor and the ACPL-339J gate driver circuit.

# Chapter 5: Typical Switching and DESAT Protection Characteristics

## 5.1 Typical Switching Losses

The EB1200-339J does not have an integrated DC bus capacitor bank; therefore, the commutation inductance (longest path from the switch to the DC bus) does depend on the setup used to characterize switching characteristic. As an example, Figure 24 and Figure 25 show the obtained turn-on and turn-off losses at 25°C for 2MBI600XNE120-50.

**Figure 24: Turn-On Switching Energy Loss at 800V DC_Bus**

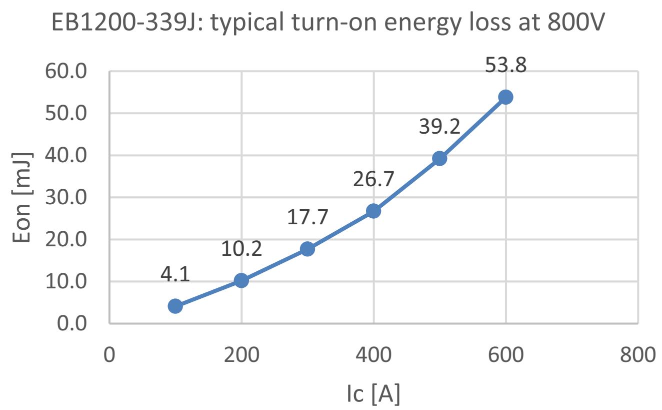
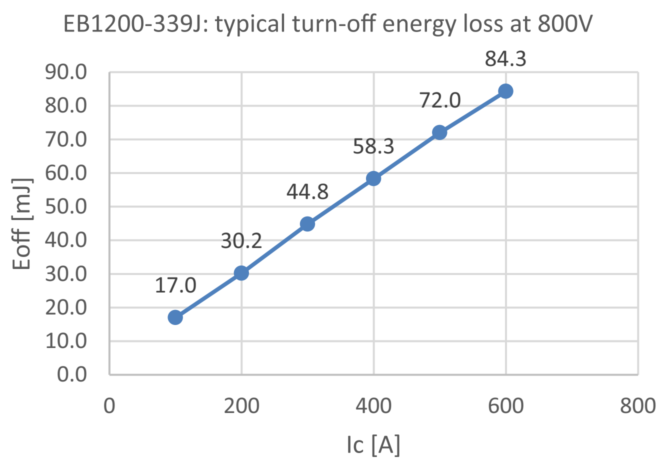



**Figure 25: Turn-Off Switching Energy Loss at 800V DC_Bus**



## 5.2 Typical Switching Waveforms

Switching waveforms during hard switching of the semiconductors are measured with an oscilloscope using the standard double pulse test procedure. Figure 26 shows the turn-on switching transient, while in the Figure 27, the turn-off switching transient is depicted.

**Figure 26: Oscilloscope Screenshot of Turn-On Transient, Vdc = 800V, Ic = 600A; CH2 (red) Ic, CH1 (green) Vce, CH3 (blue) Vge**

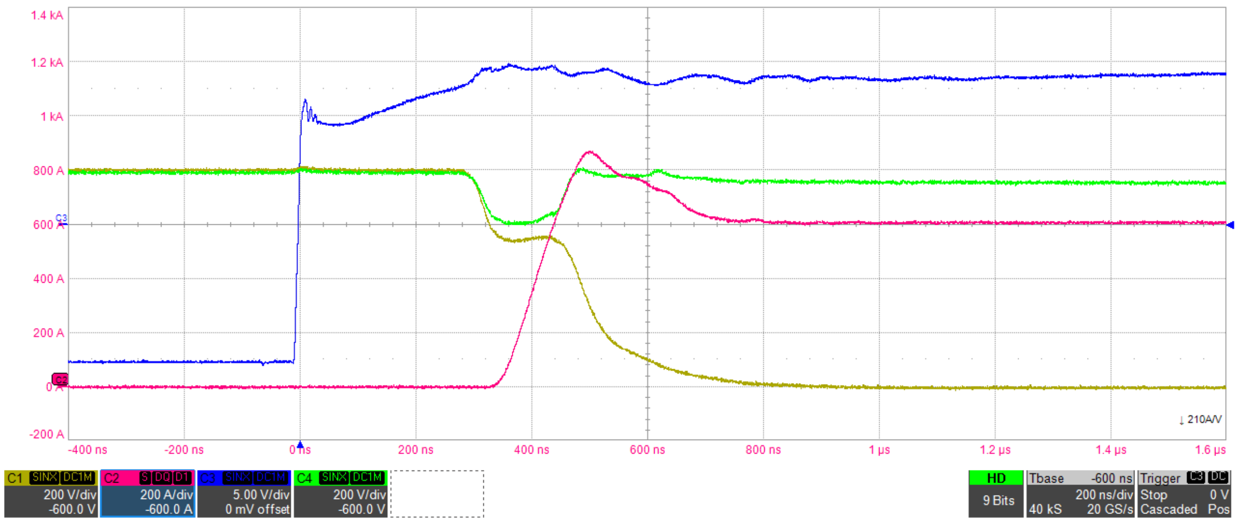
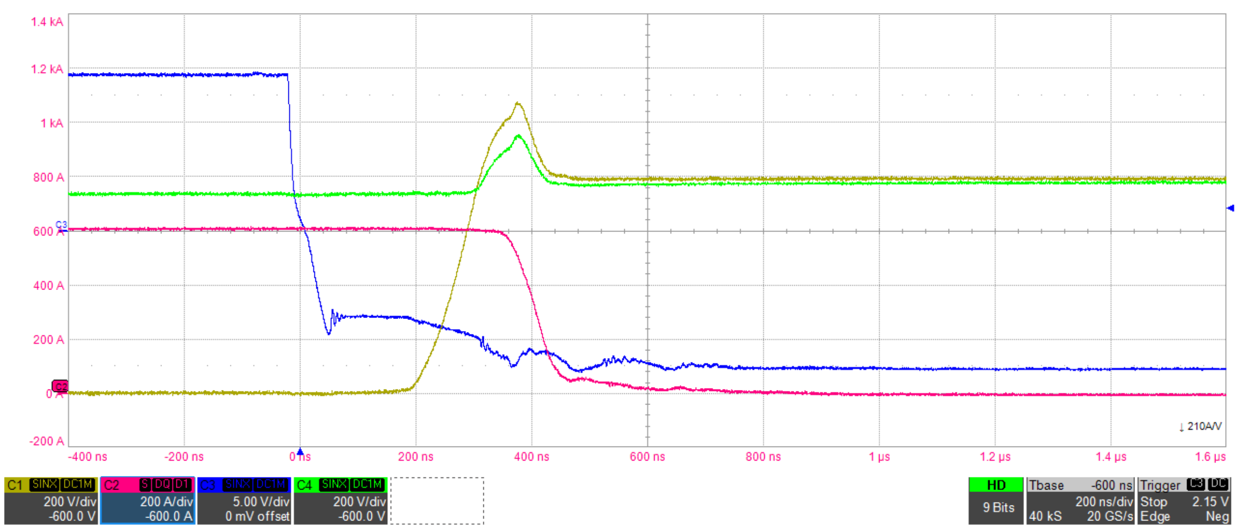


**Figure 27: Oscilloscope Screenshot of Turn-Off Transient, Vdc = 800V, Ic = 600A; CH2 (red) Ic, CH1 (green) Vce, CH3 (blue) Vge**

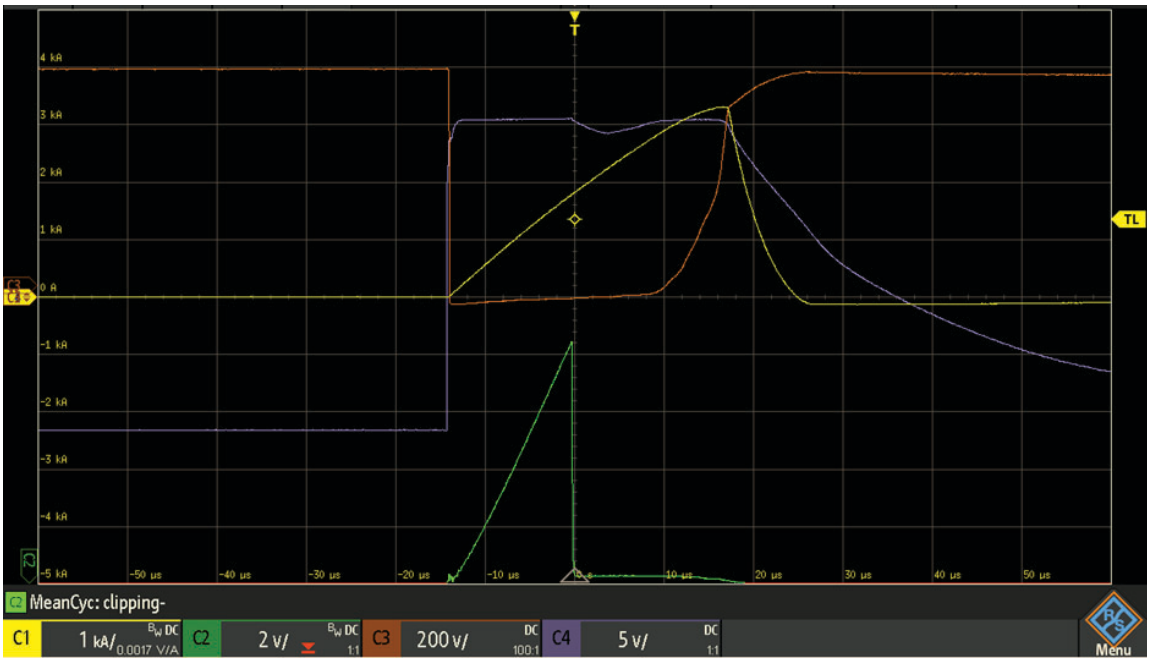


## 5.3 Typical DESAT Protection Performance

The DESAT protection function was obtained by performing the direct short circuit with 5.25 μH inductance loop to the output of the Fuji Electric's Dual XT power module 2MBI600XNE120-50. Figure 28 shows the measurement results. For evaluation purposes, results from Figure 28 were obtained with the DESAT Zener diode of $V_Z$ = 5.1V. By this adjustment, note that the DESAT function detected the short circuit condition at 3 times the nominal current. However, due to the DESAT blanking time, the current in the IGBT module was raised up to 6 times nominal. This was when the IGBT started to desaturate before the DESAT function reacted by cutting the current and performing the soft shut down function.

**NOTE:** EB1200-339J comes with the DESAT Zener diode of $V_Z$ = 2V. Depending on the IGBT module used with EB1200-339J, readjustment of the DESAT Zener diode should be considered. Select the proper DESAT Zener diode that will enable detection of the maximum 4 times nominal peak current due to a short circuit condition. For the details on DESAT Zener adjustment, refer to the ACPL-339J data sheet. If you are using the Zener diode with a lower clamp voltage, note that IGBT module desaturates at 6 times nominal current before the DESAT of the gate driver reacts. For the allowable short circuit desaturation time duration of the IGBT module, refer to its data sheet.

**Figure 28: Measurement Results from DESAT Detection, Short Circuit at $V_{DC}$ = 800V, CH1 (yellow) $I_C$, CH2 (green) $V_{DESAT}$, CH3 (brown) $V_{CE}$, CH4 (purple) $V_{GE}$**



# Chapter 6: Schematics, Layout, and BOM

This section gives full schematics, layout, and bill of materials of the EB1200-339J. The intention behind providing this information is to enable customers to modify, copy, and qualify the design for production, according to specific requirements.

## 6.1 Schematics

**Figure 29: EB1200-339J, Top-Level Sheet**

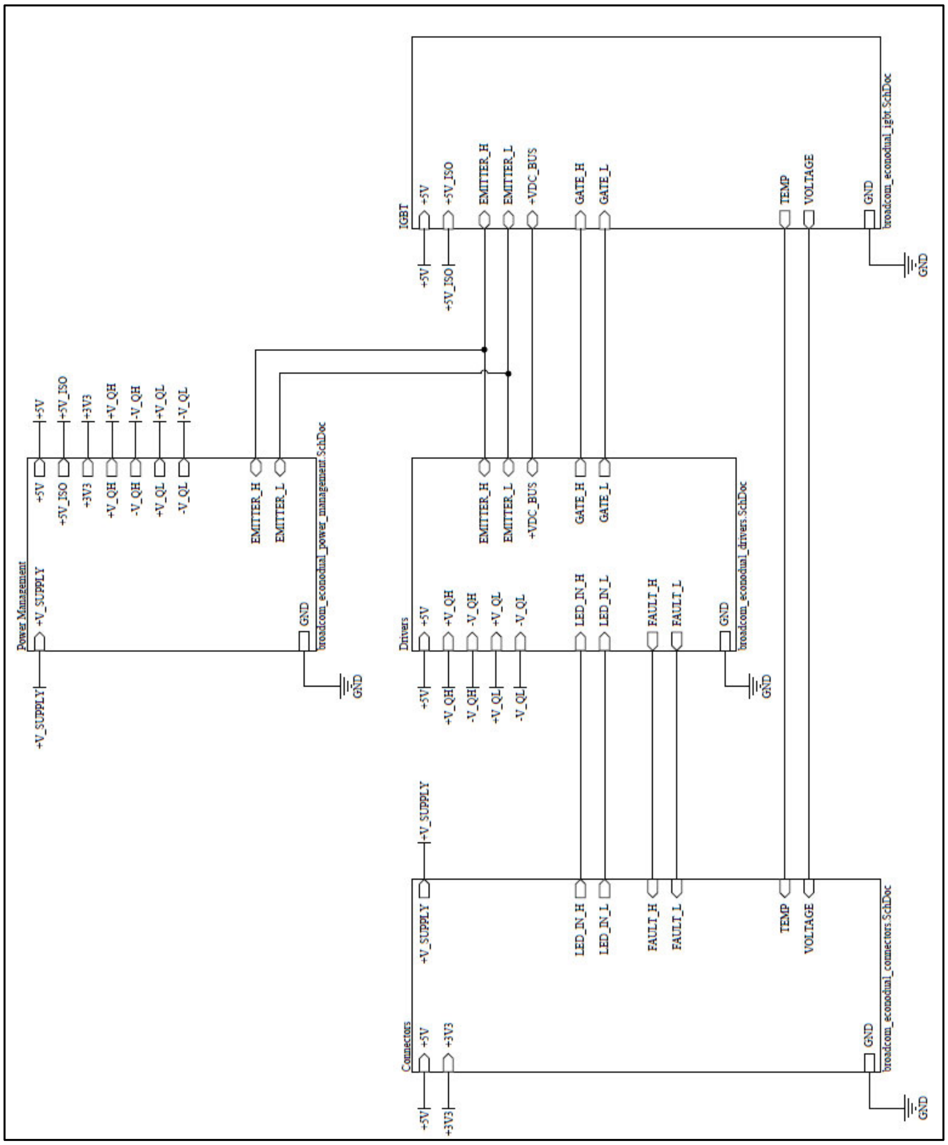


**Figure 30: EB1200-339J, Sheet 1, Connectors and Signal Buffers**

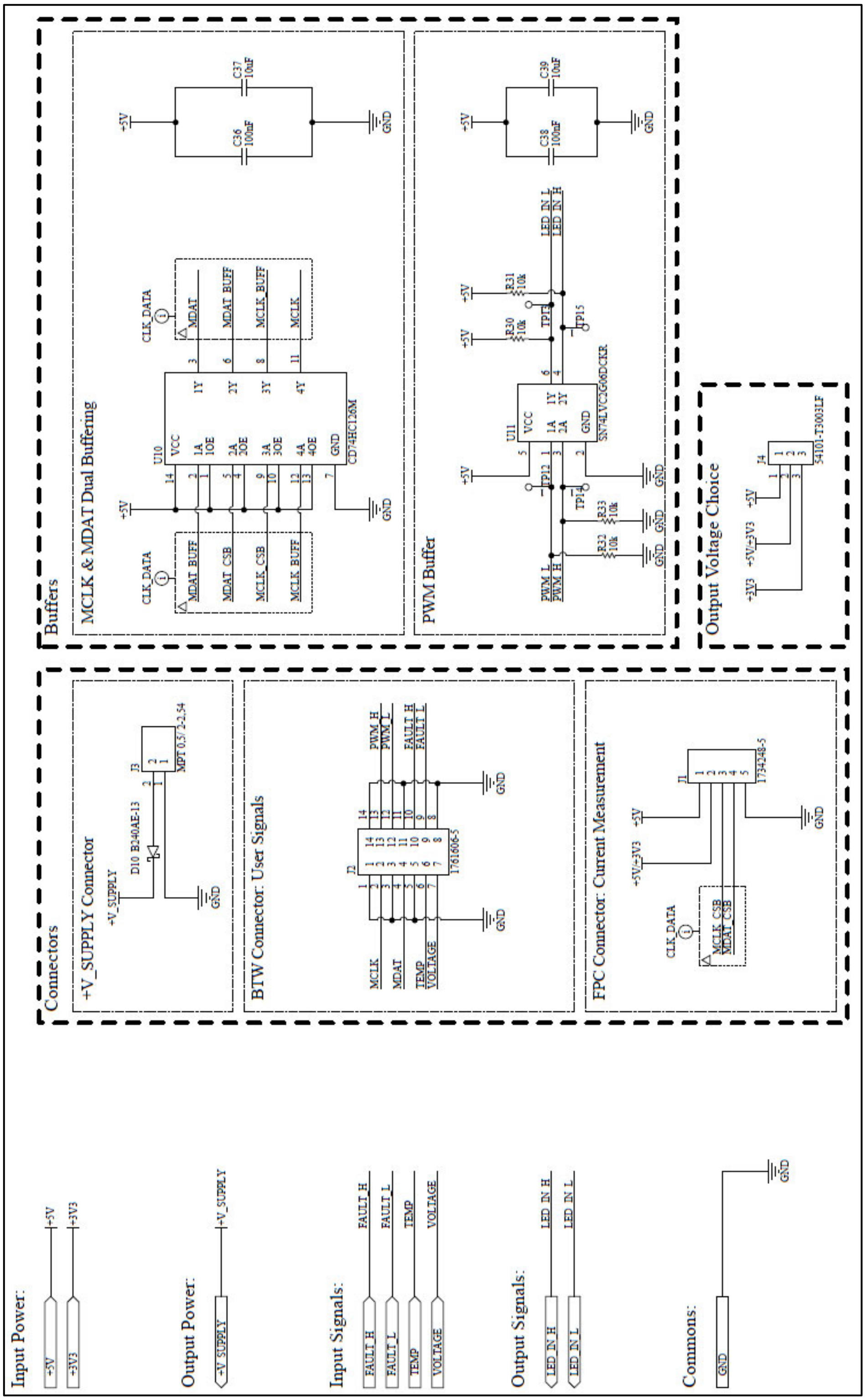


**Figure 31: EB1200-339J, Sheet 2, Gate Drivers**

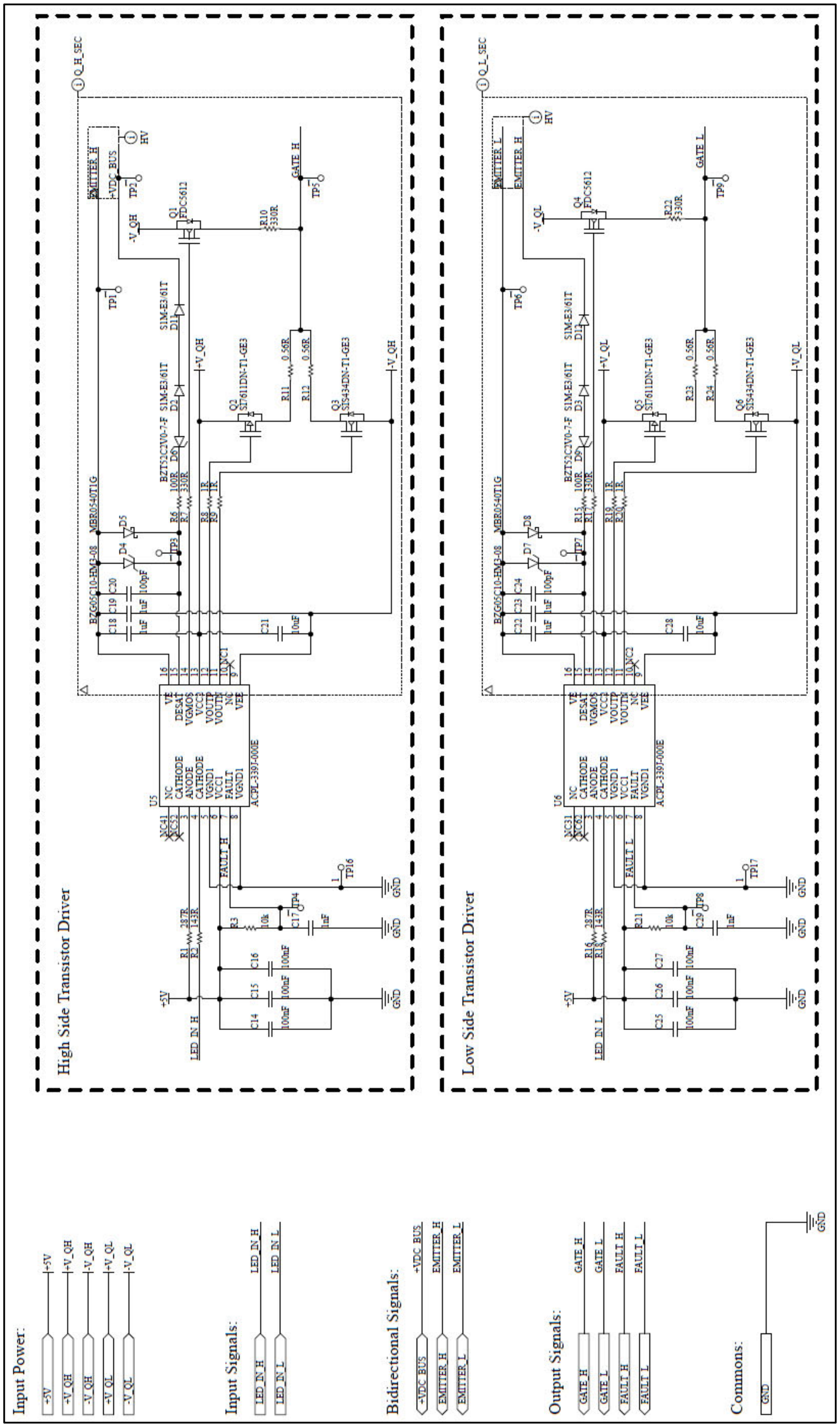
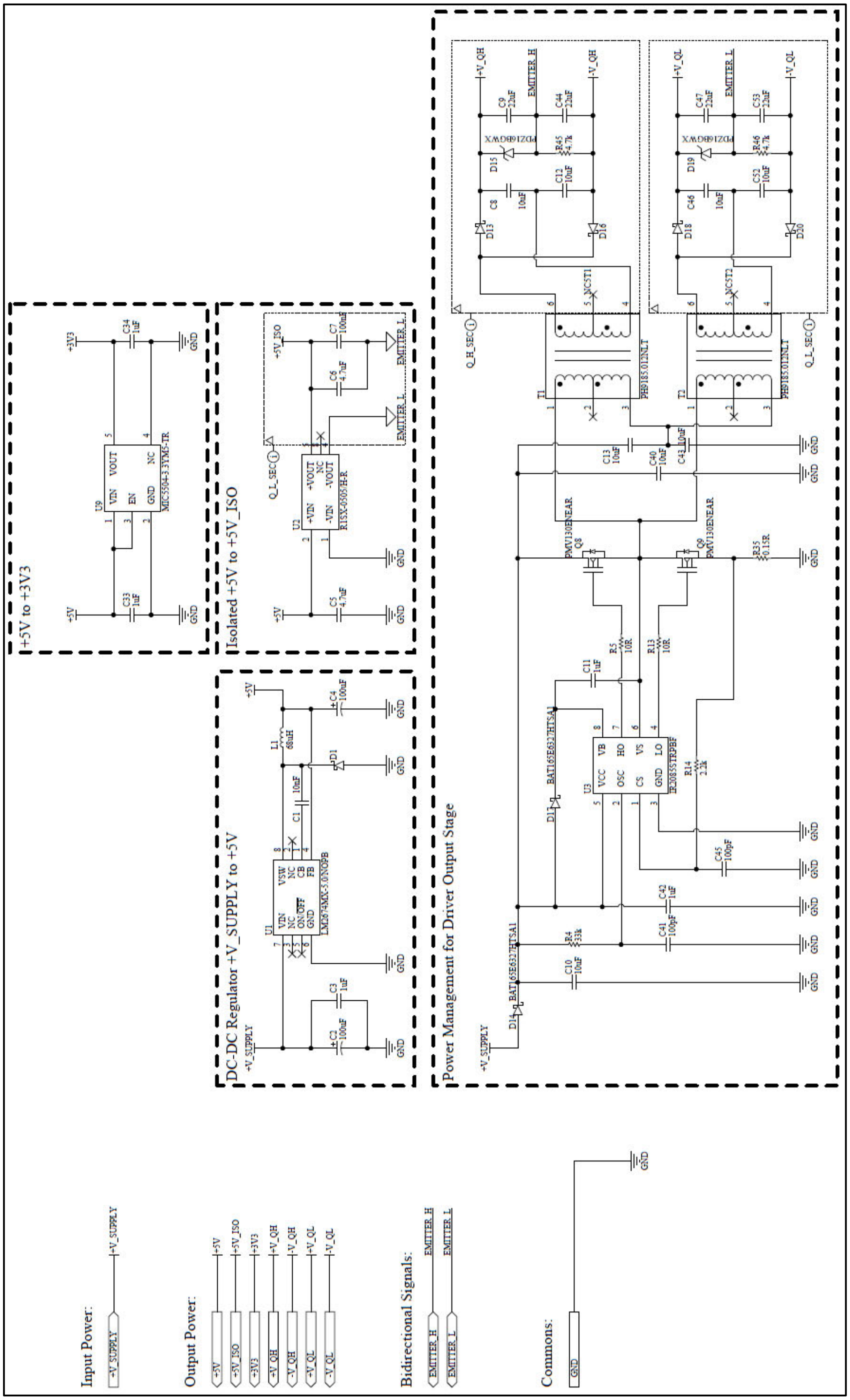


**Figure 32: EB1200-339J, Sheet 3, Measurements**



## 6.2 Layout

**Figure 33: EB1200-339J, Assembly Drawing**

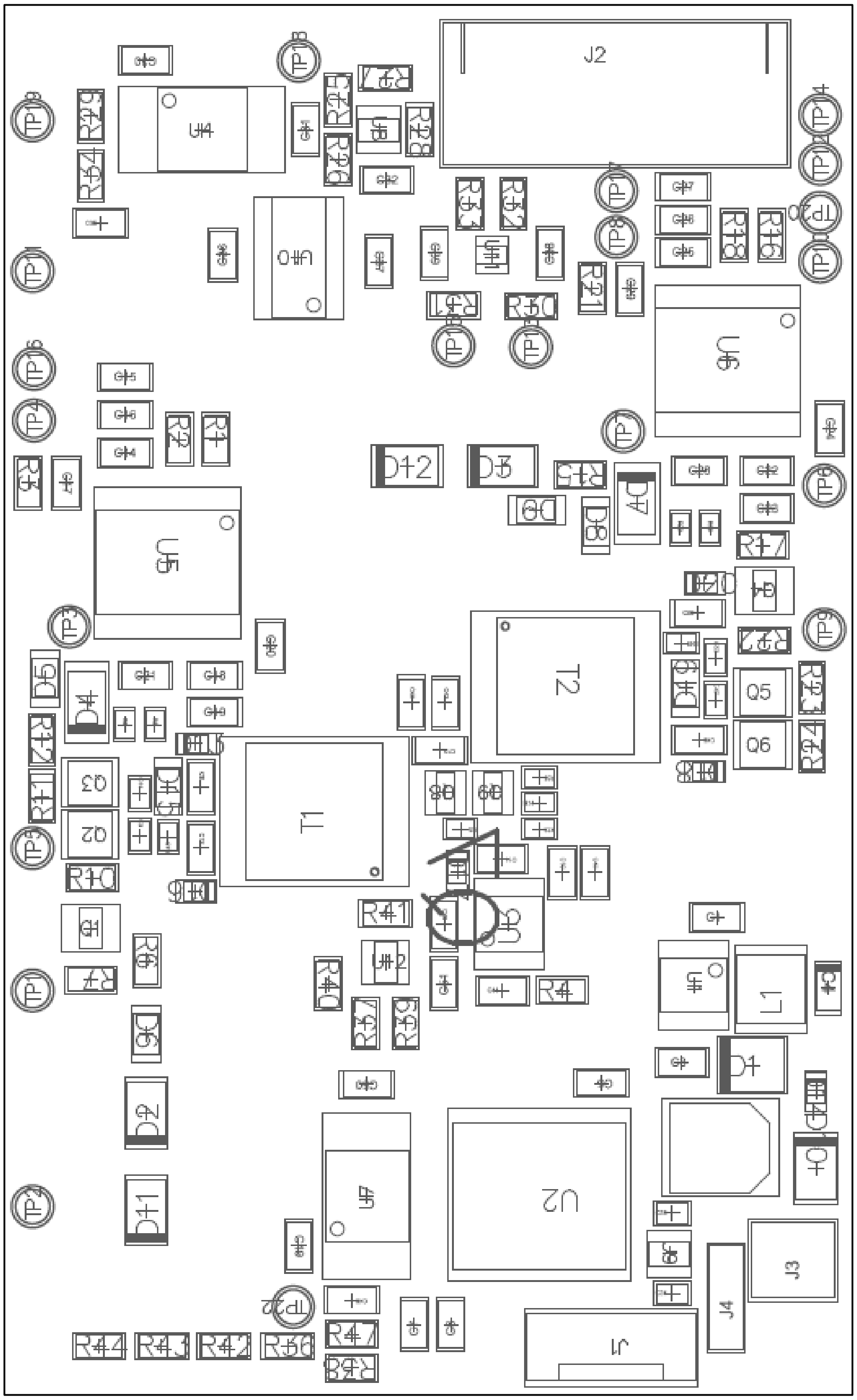


**Figure 34: EB1200-339J, Top Layer**

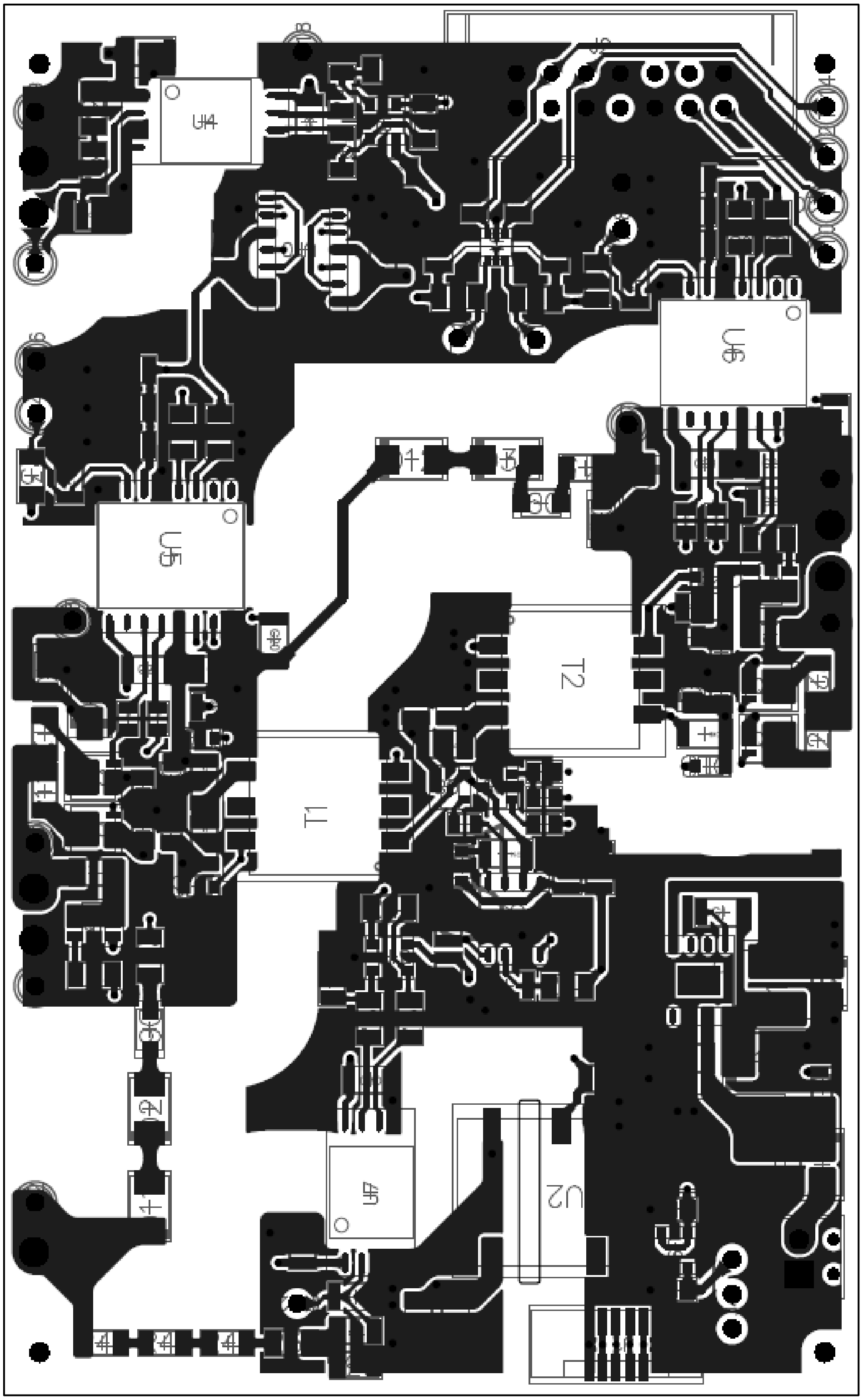


**Figure 35: EB1200-339J, Signal Layer 1**

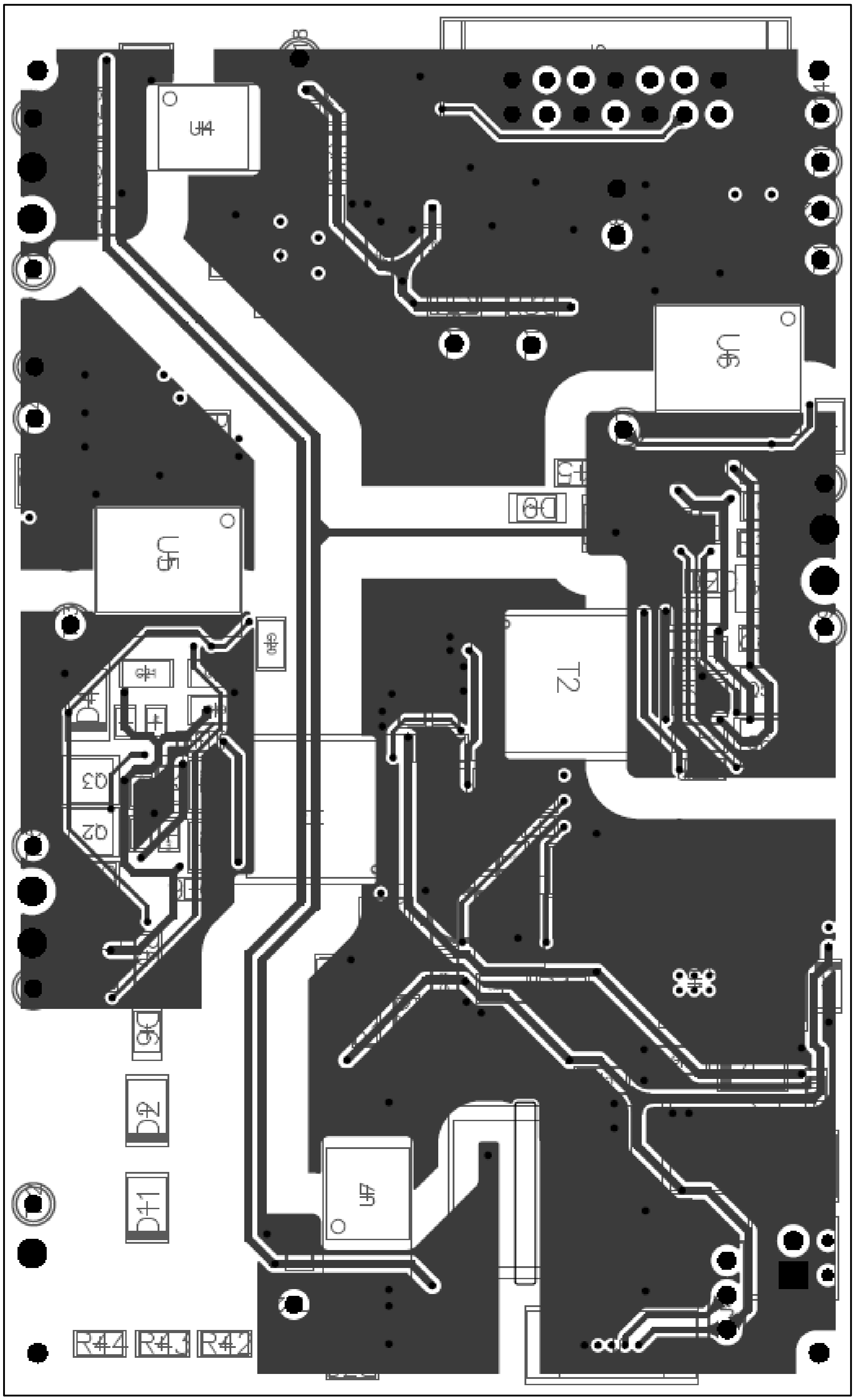


**Figure 36: EB1200-339J, Signal Layer 2**

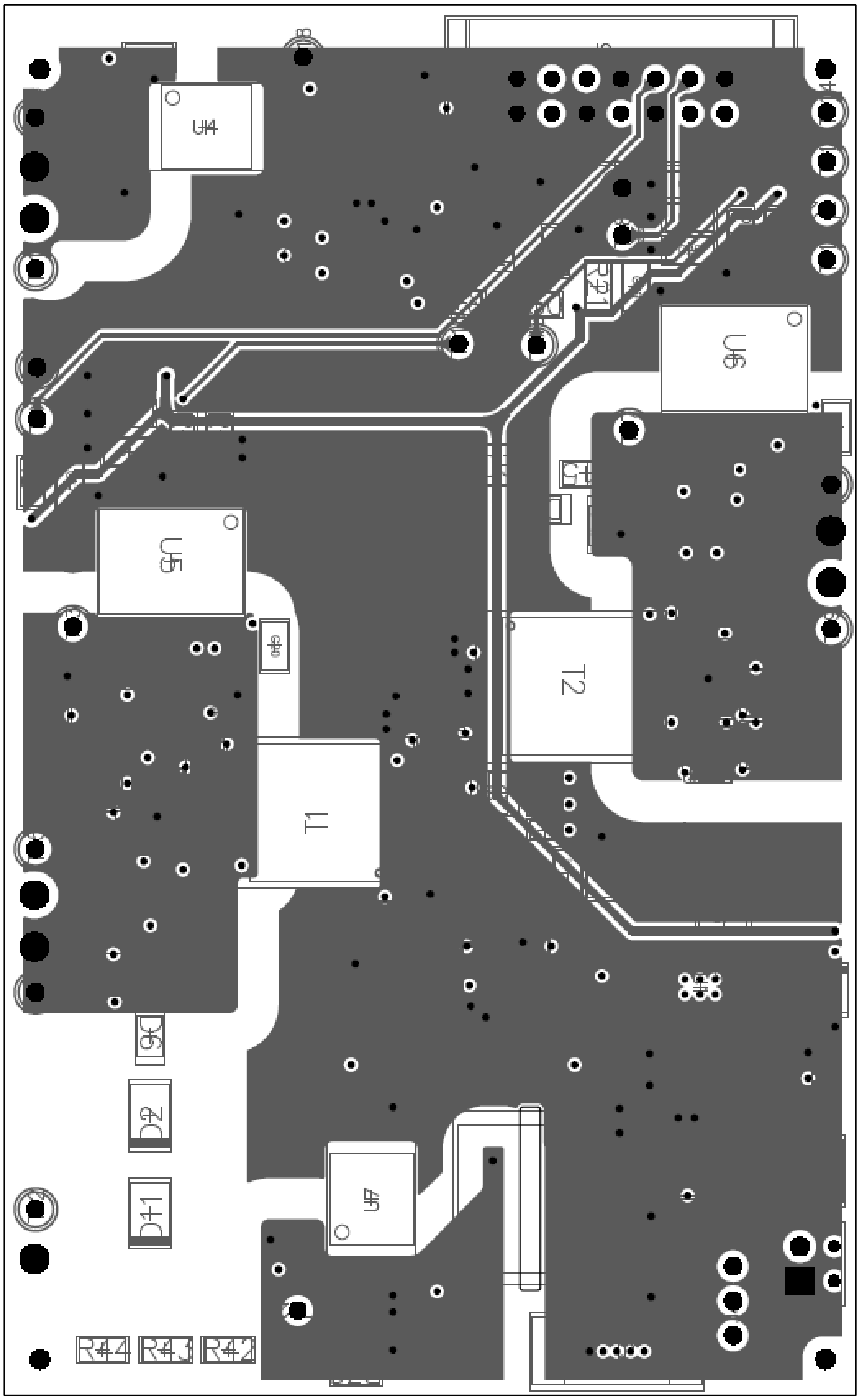
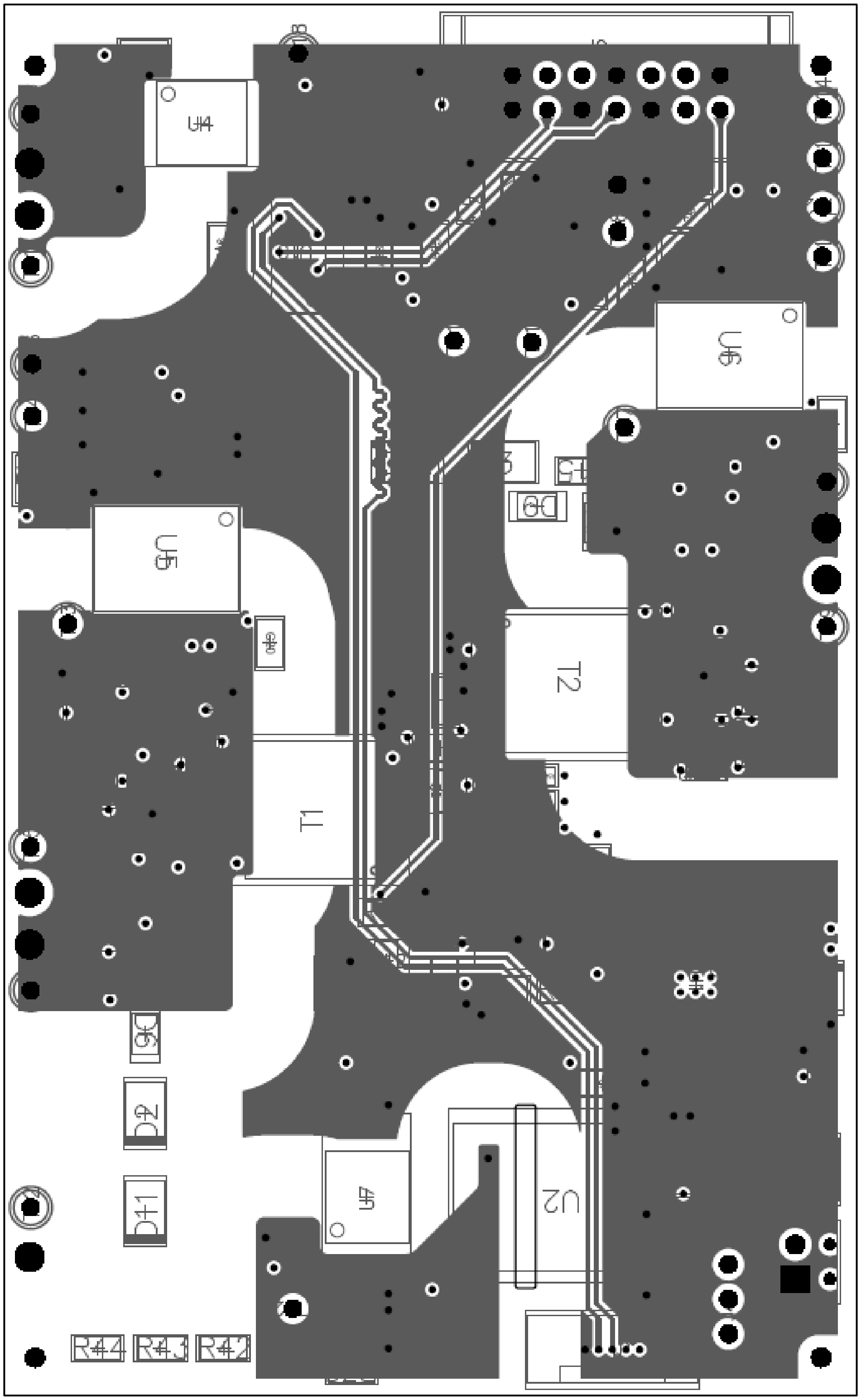


**Figure 37: EB1200-339J, Bottom Layer**



## 6.3 BOM

Bill of materials of EB1200-339J is listed in the following table.

**Table 8: Bill of Materials**

| EB1200-339J, BOM | |
|---|---|
| **Designator** | **Manufacturer Part Number** |
| C1, C48 | VJ1206Y103JXAMC |
| C2 | EEE-FT1V101AP |
| C3, C11, C18, C19, C22, C23, C42 | CC1206ZRY5V9BB105 |
| C4 | TLJA107M010R1400 |
| C5, C6 | 885012208017 |
| C7, C14, C15, C16, C25, C26, C27, C30, C31, C32, C36, C38, C49, C50, C51 | VJ1206Y104JXQCW1BC |
| C8, C10, C12, C13, C21, C28, C37, C39, C40, C43, C46, C52 | GRT31CR61H106ME01L |
| C9, C44, C47, C53 | GRM21BR61E226ME44L |
| C17, C29 | 885012208006 |
| C20, C24 | 885342208022 |
| C35 | 885012008004 |
| C41, C45 | 885012008043 |
| C33, C34 | 885382207001 |
| D1 | MBRS130LT3G |
| D2, D3, D11, D12 | S1M-E3/61T |
| D4, D7 | BZG05C10-HM3-08 |
| D5, D8 | MBR0540T1G |
| D6, D9 | BZT52C2V0-7-F |
| D10 | B240AE-13 |
| D13, D14, D16, D17, D18, D20 | BAT165E6327HTSA1 |
| D15, D19 | PDZ16BGWX |
| J1 | 1734248-5 |
| J2 | 1761606-5 |
| J3 | 1725656 |
| J4 | 54101-T3003LF |
| L1 | VLS5045EX-680M |
| Q1, Q4 | FDC5612 |
| Q2, Q5 | SI7611DN-T1-GE3 |
| Q3, Q6 | SIS434DN-T1-GE3 |
| Q7 | 2MBI600XNE120-50 |
| Q8, Q9 | PMV130ENEAR |
| R1, R16 | CRCW1206287RFKEA |
| R2, R18 | ERJ-8ENF1430V |
| R3, R21, R29, R30, R31, R32, R33, R34 | RC1206JR-0710KL |
| R38 | RK73G2BTTD1002C |
| R4 | ERJ-8ENF3302V |
| R5, R13 | CRCW080510R0FKEAC |
| R6, R15 | RC1206FR-07100RL |

**Table 8: Bill of Materials (Continued)**

| EB1200-339J, BOM | |
|---|---|
| **Designator** | **Manufacturer Part Number** |
| R7, R10, R17, R22 | CRCW1206330RFKEA |
| R8, R9, R19, R20 | RC0805FR-071RL |
| R11, R12, R23, R24 | RL73K2BR56JTD |
| R14 | RT0805FRE072K2L |
| R25, R26, R37, R39 | CRCW120693K1FKEA |
| R27, R28, R40, R41 | ERJ-8ENF1503V |
| R35 | ERJ-U6SJR15V |
| R36, R42, R43, R44 | RK73G2BTTD1004C |
| R45, R46 | RT0805FRE074K7L |
| R47 | AC1206JR-0739RL |
| T1, T2 | PH9185.012NLT |
| TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP22 | 5002 |
| U1 | LM2674MX-5.0/NOPB |
| U2 | R1SX-0505/H-R |
| U3 | IR2085STRPBF |
| U4, U7 | ACPL-C87B-000E |
| U5, U6 | ACPL-339J-000E |
| U8, U12 | ADA4891-1ARJZ-R7 |
| U9 | MIC5504-3.3YM5-TR |
| U10 | CD74HC126M |
| U11 | SN74LVC2G06DCKR |

# 6.4 Test Points

Available test points of EB1200-339J are listed in the following table.

**Table 9: Test Points**

| Test Point Designator | Signal |
|---|---|
| TP1 | EMITTER_H |
| TP2 | +VDC_BUS |
| TP3 | DESAT pin of U5 |
| TP4 | FAULT_H |
| TP5 | GATE_H |
| TP6 | EMITTER_L |
| TP7 | DESAT pin of U6 |
| TP8 | FAULT_L |
| TP9 | GATE_L |
| TP10 | TEMP |
| TP11 | Thermistor positive pin |
| TP12 | PWM_L |
| TP13 | LED_IN_L |

**Table 9: Test Points (Continued)**

| Test Point Designator | Signal |
|---|---|
| TP14 | PWM_H |
| TP15 | LED_IN_H |
| TP16 | GND |
| TP17 | GND |
| TP18 | GND |
| TP19 | EMITTER_L |
| TP20 | VOLTAGE |
| TP22 | DC Bus voltage divider |

## 6.5 Disclaimer

THIS APPLICATION NOTE CONTAINS INFORMATION THAT SHOULD SERVE ONLY AS A FIRST STEP FOR EVALUATION AND IMPLEMENTATION OF THE BROADCOM INC. TECHNOLOGIES PRODUCTS. KINESTAS DOO DOES NOT TAKE RESPONSIBILITY FOR USING AND IMPLEMENTING BROADCOM TECHNOLOGIES IN OTHER DESIGNS.

# Revision History

## Version 2.1, November 11, 2021

- Changed Dual XT and EconoDUAL IGBT to Dual IGBT throughout the document.
- Changed Dual XT and EconoDUAL modules to Dual modules in the text in Chapter 1, Introduction.
- Changed Infineon EconoDUAL modules to Infineon Dual IGBT modules in Section 1.1, Design Features.
- Changed Fuji Electric EconoDUAL Modules to Dual IGBT Modules in Table 7, Recommended $R_G$ for Different Ratings of Dual IGBT Modules.

## Version 2.0, June 8, 2020

- Added Dual XT to title and throughout reference manual.
- Updated Section 1.1, Design Features, with Infineon EconoDUAL modules.
- Updated Table 7, Recommended RG for Different Ratings of Fuji Electric EconoDUAL Modules, to add Infineon EconoDUAL modules content.
- Updated Section 4.1, Installation of EB1200-339J.
- Updated Section 5.3, Typical DESAT Protection Performance.

## Version 1.0, April 29, 2020

Initial release of this document.

BROADCOM®