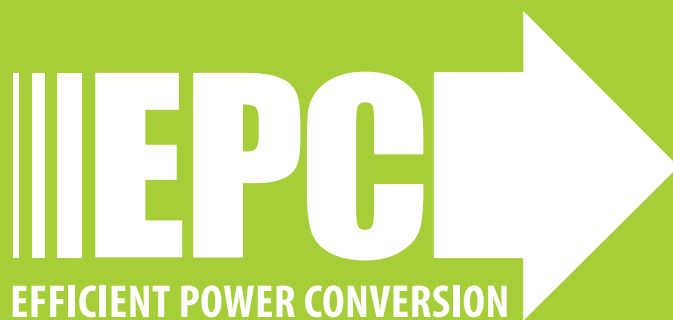


# Development Board EPC9126/EPC9126HC Quick Start Guide

*EPC2212/EPC2001C*

*100 V High Current Pulsed Laser Diode Driver*

Revision 3.0



## DESCRIPTION

The EPC9126 and EPC9126HC development boards are primarily intended to drive laser diodes with high current pulses with total pulse widths < 3 ns (half amplitude pulse width). The board is shipped with an EPC2212 or EPC2001C (HC version) enhancement mode (eGaN®) field effect transistor (FET). The EPC2212 is an AEC-Q101 automotive qualified 100 V FET capable of current pulses up to 75 A, and the EPC2001C is a 100 V FET capable of current pulses up to 150 A. The development boards used the same printed circuit board with minor component changes in addition to the different FETs. Due to the fact that the basic design and behavior of the boards is nearly the same, the term EPC9126xx will be used to refer to either board, and only when necessary will one or the other board be called attention to. The EPC9126xx ships with the EPC9989 interposer board. The EPC9989 has a collection of break-away 5 mm square interposer PCBs with footprints for different lasers and a collection of other footprints. The use of the interposers allows many different lasers or other loads to be mounted while still being able to use the EPC9126xx. The boards do not include a laser diode, which must be supplied by the user.

The EPC9126xx comprises a ground-referenced eGaN FET driven by a Texas Instruments LMG1020 gate driver. The EPC9989 interposer provides multiple options for mounting laser diodes. The printed circuit board is designed to minimize the power loop inductance while maintaining mounting flexibility for the laser diode or other load. It includes multiple on-board passive probes for voltages and discharge capacitor current, and is equipped with SMA connections for input and sensing designed for 50 ohm measurement systems. In addition, the board includes a narrow pulse generator capable of sub-nanosecond precision, or the user can simply send the input to the gate drive directly. Finally, the board can also be used for other applications requiring a ground-referenced eGaN FET, e.g. Class E amplifiers or similar. A complete block diagram of the circuit is given in figure 1, and a detailed schematic in figure 7.

For more information on the EPC2212C or EPC2001C eGaN FETs, please refer to the datasheets available from EPC at [www.epc-co.com](http://www.epc-co.com). The datasheet should be read in conjunction with this quick start guide. In addition, there is an application note, [AN027 eGaN FETs for Lidar – Getting the Most Out of the EPC9126 Laser Driver](#). While the note discusses Rev. 2 of the EPC9126xx, most of the information is applicable to Rev. 3.

## SETUP AND OPERATION

Development board EPC9126xx is easy to set up to evaluate the performance of the EPC2212 or EPC2001C(HC version) eGaN FET. Refer to Figure 2 for proper connect and measurement setup and follow the procedure below:

1. **Review laser safety considerations. Observe all necessary laser safety requirements including the use of personal protection equipment (PPE) as required. Refer to qualified safety personnel as necessary.**
2. With power off, install laser diode U2 or other load. The use of one of the interposers from the included EPC9989 be used to mount the laser or other load, and this is discussed in the section Laser Diode and Load Considerations for further information.

**Table 1: Performance Summary (T<sub>A</sub> = 25°C) EPC9126 and EPC9126HC**

| Symbol             | Parameter                   | Conditions | Min | Nom | Max | Units |
|--------------------|-----------------------------|------------|-----|-----|-----|-------|
| V <sub>Logic</sub> | Gate drive and logic supply |            | 6   |     | 12  | V     |
| V <sub>BUS</sub>   | Bus Input Voltage Range     |            | 0   |     | 80  | V     |
| Z <sub>IN</sub>    | Input impedance             |            |     | 50  |     | Ω     |
| V <sub>INPUT</sub> | Input pulse range           |            | 0   |     | 5   | V     |
| T <sub>Pin</sub>   | Input pulse width           |            | 1   |     |     | ns    |

**SAFETY WARNING:** This board is capable of driving laser diodes to generate high peak power optical pulses. Such pulses are capable of creating PERMANENT VISION DAMAGE. Laser diodes may emit infrared (IR) light that is invisible, but which can still cause PERMANENT VISION DAMAGE. User is fully responsible for following proper laser safety procedures to prevent vision damage.

3. With power off, connect the input power supply bus to +V<sub>BUS</sub> (J2) and ground / return to -V<sub>BUS</sub> (J2) or GND.
4. With power off, connect the logic supply (7-12 VVDC) to +V<sub>Logic</sub> or GND.
5. With power off, connect the signal pulse generator to the input J5. J5 is terminated with 50 Ω on the EPC9126, and is designed for a 5 V logic input. The signal input can handle up to 0.25 W RMS (3.5 V RMS), which corresponds to a 50% duty cycle at 5 V. This pulse specification is for the input only, and the user will have to make informed choices regarding the rest of the circuit.
6. Connect the remaining measurement SMA outputs to an oscilloscope, using 50 Ω cables and with the scope inputs set to 50 Ω impedance. See section Measurement Considerations for more information, including the attenuation values for each output.
7. Turn on the logic supply voltage to a value within the specifications.
8. Turn on the bus voltage to a value within the specification.
9. Turn on the pulse source and observe switching operation via the outputs and any additional desired probing. Laser diode output may be observed with an appropriate electro-optical receiver.
10. Once operational, adjust the bus voltage, input pulse width, and pulse repetition frequency (PRF) as desired within the operating range and observe the system behavior.
11. For shutdown, please follow steps in reverse.

**NOTE:** When measuring the high frequency content switch node, care must be taken to avoid long ground leads. Measure the switch node by placing the oscilloscope probe tip through the large via on the switch node (designed for this purpose) and grounding the probe directly across the GND terminal provided. See Figure 3 for proper scope probe technique.

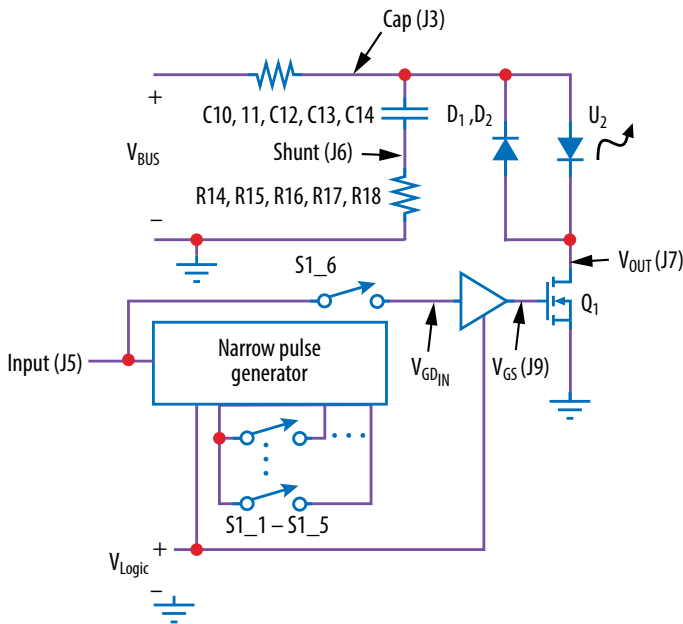


Figure 1: Block diagram of EPC9126xx development board

### OPERATING PRINCIPLE

The EPC9126xx is shipped as a capacitive discharge laser diode driver. Please refer to the block diagram (figure 1) and the schematic (figure 7). It has several possible modifications (section MODIFICATIONS), but only the basic operation will be covered in this section. The EPC9126xx basic operating principle is to discharge energy storage capacitance {C10, C11, C12, C13, C14} through the laser diode, and then recharge {C10, C11, C12, C13, C14} through the resistor bank {R2, R3, R5, R6}.

The discharge is controlled via an input pulse that is delivered to SMA connector J5, which is terminated on the demo board with 50 Ω. As shipped, SW1\_6 is turned on, and this pulse is delivered to gate driver U5. When the input goes high, the gate driver turns on Q1, allowing {C10, C11, C12, C13, C14} to discharge through the laser diode U2. When the input goes low, Q1 turns off. If there is current remaining in the power loop, diodes D1, D2 (if added by user) can conduct and help prevent overvoltage of the laser and FET.

Measurements of many of the main waveforms can be made through the SMA test points provided. These test points can provide waveform measurements with equivalent bandwidths > 3 GHz. As a result, they have requirements and properties that differ from most conventional oscilloscope probes. More details on the usage of these test points is provided in section MEASUREMENT CONSIDERATIONS.

For further details on lidar driver circuits, it is recommended to read the application note Getting the Most out of eGaN FETs and Your EPC9126 Laser Driver (AN027), available at [www.epc-co.com](http://www.epc-co.com). While this application note refers to V2.5 of the EPC9126xx, the basic principles and design methods are still applicable.

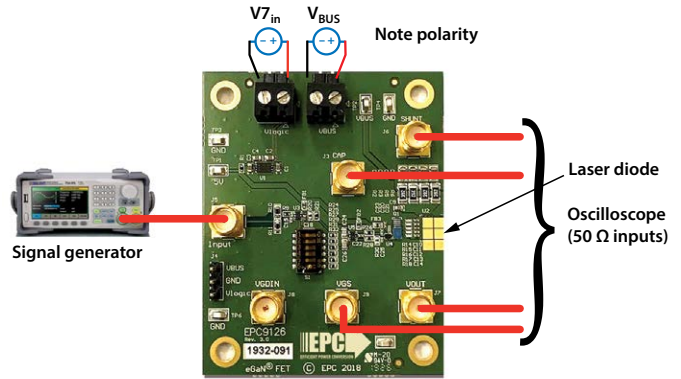


Figure 2: Connection and measurement setup

### LASER DIODE OR LOAD CONSIDERATIONS

The EPC9126xx can be used as is to mount a laser diode or other load. Figure 3 highlights the output pad locations. However, many laser suppliers have different mounting footprints, making it difficult to optimize the performance of the driver and still maintain the desired flexibility. The use of an interposer PCB provides a solution to this problem with only a small added performance penalty. The EPC9126xx Rev. 3 ships with the EPC9989 interposer PCB, shown in figure 4. The EPC9989 has an assortment of 5 mm square interposer PCBs that can be snapped off the board. These interposers have various footprints on the top side that can accommodate several surface mount laser diodes, an MMCX connector, and several patterns designed to accommodate a wide variety of possible loads. These interposers mount between the EPC9126xx and the laser diode or other load. Figure 5 shows an example of an Excelitas SMD laser diode mounted with one of the interposers. The product key indicating which laser diode packages correspond to the mounting locations is shown in figure 6.

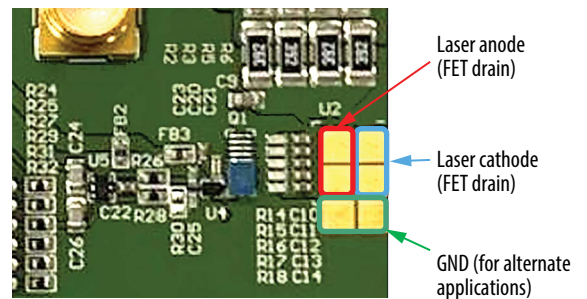


Figure 3: Output terminals of EPC9126xx

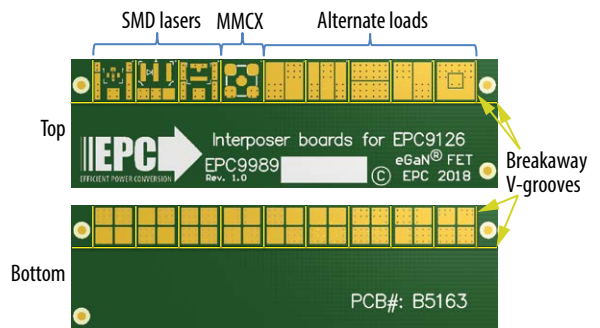


Figure 4: EPC9989 interposer PCB

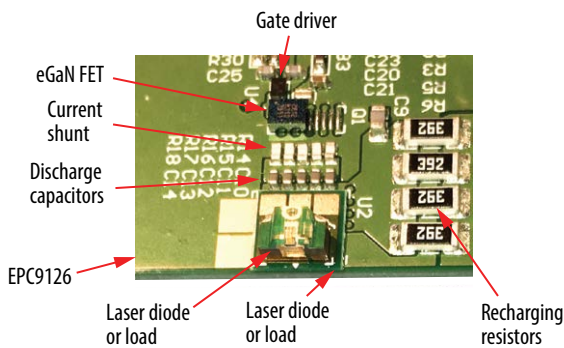


Figure 5: Laser mounted to EPC9126xx using interposer

The recommended use of the interposer is the following:

1. Apply solder paste to the U2 pads on the EPC9126xx PCB.
2. Apply solder paste to the appropriate pads on the top side of the interposer.
3. Carefully position the desired interposer with the bottom side facing the top side of the EPC9126xx on the U2 footprint.
4. Position the laser diode or desired load on the interposer.
5. Reflow with the recommended temperature profile for the solder used. The use of a reflow oven that can meet the recommended soldering specifications is highly recommended. Other reflow methods may also be used based on the experience of the user.

The power loop inductance, including that of the laser diode, is a primary factor that determines the shape of the laser pulse. Considerable effort has been made to minimize power loop inductance while maximizing the choice of laser diode and its orientation. The discharge caps, current sense resistors, and the eGaN FET must all be mounted in close proximity to minimize inductance. As a result, the user must take care not to damage any components when mounting the laser or changing other components in the power loop.

Laser diode current pulses can result in peak powers of several hundred watts to over 1 kW. Laser diodes for lidar applications are designed with this in mind, but thermal limitations of the laser package mean that pulse widths, duty cycles, and pulse repetition frequency limitations must be observed. Read laser diode data sheets carefully and follow any manufacturers' recommendations.

This board has been tested with the following laser diodes: TPGAD1S09H from Excelitas (<http://www.excelitas.com>).

Table 2: Properties of SMA test points

| Designator | PCB label          | Description  | Attenuation factor                         | DC blocking cap | LF time constant | Internal 50 Ω termination |
|------------|--------------------|--|--|-----------------|------------------|---------------------------|
| J3         | CAP                | Discharge capacitor voltage (VCHARGE on schematic) | 41 V/V                                     | 10 nF           | 10 μs            | YES                       |
| J6         | SHUNT              | Discharge shunt voltage                            | 21.2 A/V (EPC9126)<br>45.5 A/V (EPC9126HC) | NO              | N/A              | NO                        |
| J7         | V <sub>OUT</sub>   | Q1 drain voltage                                   | 41 V/V                                     | 10 nF           | 10 μs            | YES                       |
| J9         | V <sub>GD,IN</sub> | Gate drive input                                   | 20   | NO              | N/A              | NO                        |
| J10        | V <sub>GS</sub>    | Q1 gate voltage                                    | 20   | NO              | N/A              | NO                        |

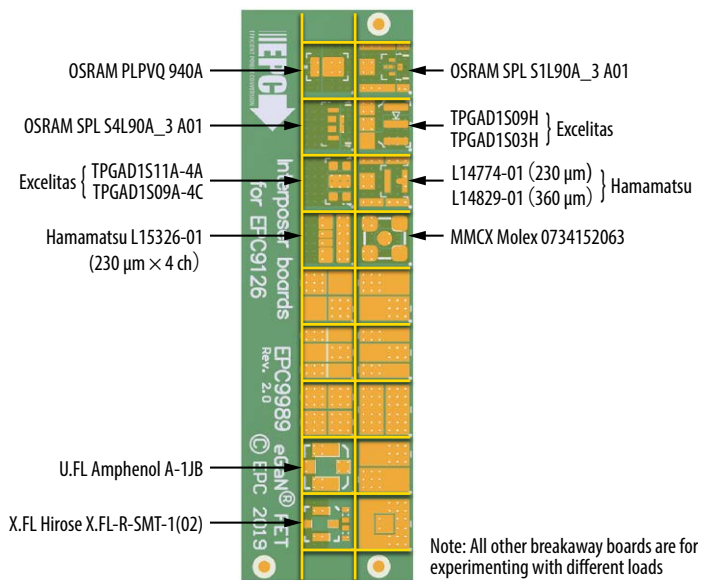


Figure 6: Product key indicating which laser diode packages correspond to the mounting location of EPC9989 interposer board.

## MEASUREMENT CONSIDERATIONS

SMA jacks are provided to measure several voltages in the circuit, including gate drive input, Q1 gate voltage, Q1 drain voltage, charge voltage of the energy storage cap, and the sense voltage of the discharge cap current measurement shunt. All measurement points are designed to be terminated in 50 Ω, hence when viewing waveforms, the oscilloscope inputs should be set to a 50 Ω input. Ideally, unused inputs should be also terminated with a 50 Ω load to prevent the probes from creating additional resonances. The Q1 drain voltage and the discharge cap sense voltage have on-board terminations to greatly reduce this effect, and in practice, the remaining resonances may be small or otherwise tolerable. It is recommended that the user verify this for their own requirements.

All sense measurement SMAs, except for the shunt measurement, use the transmission line probe principle to obtain waveform fidelity at sub-ns time scales. They have been verified to produce near-identical results to a Tektronix P9158 3 GHz transmission line probe. As a result of their design, they have a built-in attenuation factor. In addition, the impedance of the probes is relatively small, and as a result, the test points for high voltage measurements include a DC blocking capacitor. If long pulse widths are used, these test points may yield erroneous results, and an external probe should be used.

The current shunt is designed to estimate the discharge capacitor current. Substantial effort has been made to reduce the inductive effects of the current shunt, both through the use of carefully selected resistors and a compensation network to help compensate for the shunt equivalent series resistance. However, the shunt is a compromise between current measurement accuracy and minimizing the impact on the laser driver performance. If a more accurate shunt waveform measurement is desired, the shunt resistors may be replaced with ones that provide higher accuracy. This is likely to require higher resistor values, which can contribute to errors in the capacitor voltage measurement and in increased power dissipation. Finally, note that the capacitor current also includes the current due to D1 and D2 (if included), and PCB capacitance.

Table 2 summarizes the properties of the SMA test points for ease of reference.

## OTHER FEATURES

### Narrow pulse generator:

Many signal generators cannot produce an accurate, short pulse. The EPC9126xx includes a function to obtain narrow output pulses, following a method given in Section 8.2.2.2 of the Texas Instruments LMG1020 data sheet. This is controlled through DIP switch S1. For normal operation, position 6 should be ON, and the positions 1 through 5 should be OFF. In this case, the input pulse to J5 will be passed to the gate drive unmodified.

To operation the narrow pulse generator, move position 6 to OFF. The pulse input to J5 is now a trigger pulse and must be set to at least 60 ns, with at least 300ns off time between pulses. The pulse width can now be adjusted via S1 switch positions 1 through 5. For best results, keep position 1 in the OFF state. For very narrow pulses, the position 1 switch may be turned ON, but reliable operation cannot be expected. Approximate pulse width values are summarized in Table 3. Since these values are approximate, user must verify as necessary.

### Modifications:

While diodes D1 and D2 can provide some protection to FET Q1 and laser D3, they have parasitic inductance and capacitance that can reduce performance at the very fastest speeds. Hence, they are not populated, and it is left to the user to determine whether they are necessary for a particular application.

The value of the shunt resistors can be increased up to a point to improve the discharge cap current sense accuracy. Note that accurate measurement of current while inserting extremely low inductance into the power loop is extremely challenging, and many factors must be considered. For the lowest possible inductance, the resistors can be replaced with copper foil if no sensing is needed.

The value of the energy storage cap {C11, C12, C13, C14, C15} can be modified as desired, as well as the recharge resistor {R2, R3, R5, R6}. In the extreme case, the resistor may be reduced to 0 Ω for cases where a capacitive discharge pulse is not desired.

**Table 3: Narrow pulse generator switch settings with S1 Pos 6 = OFF. (a): POS 1 = OFF (recommended). (b) POS 1 = ON (not recommended for reliable operation).**

| Switch setting (Pos 1 = OFF) |   |   |   |   |   | Pulse width (ns) |
|------------------------------|---|---|---|---|---|------------------|
| 6                            | 5 | 4 | 3 | 2 | 1 |                  |
| 0                            | 0 | 0 | 0 | 0 | 0 | 60.4             |
| 0                            | 1 | 0 | 0 | 0 | 0 | 38.1             |
| 0                            | 0 | 1 | 0 | 0 | 0 | 18.5             |
| 0                            | 1 | 1 | 0 | 0 | 0 | 11.5             |
| 0                            | 0 | 0 | 1 | 0 | 0 | 9.3              |
| 0                            | 1 | 0 | 1 | 0 | 0 | 6.6              |
| 0                            | 0 | 1 | 1 | 0 | 0 | 5.5              |
| 0                            | 1 | 1 | 1 | 0 | 0 | 5.1              |
| 0                            | 0 | 0 | 0 | 1 | 0 | 4.9              |
| 0                            | 1 | 0 | 0 | 1 | 0 | 3.4              |
| 0                            | 0 | 1 | 0 | 1 | 0 | 2.9              |
| 0                            | 1 | 1 | 0 | 1 | 0 | 2.4              |
| 0                            | 0 | 0 | 1 | 1 | 0 | 2.1              |
| 0                            | 1 | 0 | 1 | 1 | 0 | 1.9              |
| 0                            | 0 | 1 | 1 | 1 | 0 | 1.7              |
| 0                            | 1 | 1 | 1 | 1 | 0 | 1.2              |

(a)

| Switch setting (Pos 1 = ON) |   |   |   |   |   | Pulse width (ns) |
|-----------------------------|---|---|---|---|---|------------------|
| 6                           | 5 | 4 | 3 | 2 | 1 |                  |
| 0                           | 0 | 0 | 0 | 0 | 1 | 1.6              |
| 0                           | 1 | 0 | 0 | 0 | 1 | 1.46             |
| 0                           | 0 | 1 | 0 | 0 | 1 | 1.32             |
| 0                           | 1 | 1 | 0 | 0 | 1 | 1.17             |
| 0                           | 0 | 0 | 1 | 0 | 1 | 0.96             |
| 0                           | 1 | 0 | 1 | 0 | 1 | 0.65             |
| 0                           | 0 | 1 | 1 | 0 | 1 | 0.45             |
| 0                           | 1 | 1 | 1 | 0 | 1 | 0.32             |
| 0                           | 0 | 0 | 0 | 1 | 1 | 0.3              |
| 0                           | 1 | 0 | 0 | 1 | 1 | 0                |
| 0                           | 0 | 1 | 0 | 1 | 1 | 0                |
| 0                           | 1 | 1 | 0 | 1 | 1 | 0                |
| 0                           | 0 | 0 | 1 | 1 | 1 | 0                |
| 0                           | 1 | 0 | 1 | 1 | 1 | 0                |
| 0                           | 0 | 1 | 1 | 1 | 1 | 0                |
| 0                           | 1 | 1 | 1 | 1 | 1 | 0                |

(b)

**Table 4: Bill of Materials - EPC9126xx**

| Item | Quantity | Reference                    | Part Description   | Manufacturer            | Part Number  |
|------|----------|------------------------------|--|-------------------------|--|
| 1    | 1        | C1                           | Capacitor, 4.7 $\mu$ F, 25 V, X5R  | TDK                     | C1608X5R1E475K080AC  |
| 2    | 5        | C10, C11, C12, C13, C14      | Capacitor, 220 pf, 100 V, NP0 (EPC9126)<br>Capacitor, 560 pf, 100 V, NP0 (EPC9126HC) | TDK                     | C1005C0G2A221J050BA (EPC9126)<br>C1005C0G2A561J050BC (EPC9126HC) |
| 3    | 3        | C15, C23, C25                | Capacitor, 5 pf, 50 V, NP0   | TDK                     | C1005C0G1H050C050BA  |
| 4    | 2        | C16, C17                     | Capacitor, 5 pf, 50 V, NP0   | TDK                     | C1005C0G1H050C050BA  |
| 5    | 3        | C18, C20, C22                | Capacitor, 100 nf, 25 V, X7R   | TDK                     | C1005X7R1E104K050BB  |
| 6    | 3        | C2, C3, C4                   | Capacitor, 1 $\mu$ F, 50 V, X7R  | Taiyo Yuden             | UMK107AB7105KA-T   |
| 7    | 1        | C21                          | Capacitor, 100 nf, 16 V, X5R   | TDK                     | C0510X5R1C104M030BC  |
| 8    | 2        | C24, C26                     | Capacitor, 8 pf, 50 V, NP0   | Murata                  | GRM1885C1H8R0BA01D   |
| 9    | 4        | C5, C6, C7, C8               | Capacitor, 1 $\mu$ F, 100 V, X7R   | TDK                     | CGA4J3X752A105K125AE   |
| 10   | 2        | C9, C19                      | Capacitor, 10 nf, 100 V, NP0   | TDK                     | C1608C0G2A103J080AC  |
| 11   | 3        | FB1, FB2, FB3                | Ferrite bead, 330 $\Omega$ , 700 mA  | TDK                     | MPZ10055331ET000   |
| 12   | 2        | J1, J2                       | Board to wire connector, 2 position  | Tyco Electronics        | 1776113-2  |
| 13   | 6        | J3, J5, J6, J7, J8, J9       | Female SMA SMD   | Molex                   | 0732511350   |
| 14   | 1        | J4                           | Header, 3x1 0.1 Male Vert.   | Tyco                    |  |
| 15   | 1        | Q1                           | 100 V 18A 13.5 m $\Omega$ (EPC9126)<br>100 V 25A 7 m $\Omega$ (EPC9126HC)            | EPC                     | EPC2212 (EPC9126)<br>EPC2001C (EPC9126HC)                        |
| 16   | 1        | R1                           | Resistor, 0, 0402  | Panasonic               | ERJ-2GE0R00X   |
| 17   | 2        | R10, R11                     | Resistor, 100, 1%, 0603  | Vishay                  | MCT0603MC1000FP500   |
| 18   | 1        | R12                          | Resistor, 49.9, 1% 0402  | Panasonic               | ERJ-2RKF49R9X  |
| 19   | 1        | R13                          | Resistor, 0, 0402  | Panasonic               | ERJ-2GE0R00X   |
| 20   | 5        | R14, R15, R16, R17, R18      | Resistor, 0.47, 1%, 0402 (EPC9126)<br>Resistor, 0.22, 1%, 0402 (EPC9126HC)           | Rohm                    | UCR01MVPFLR470 (EPC9126)<br>UCR01MVPFLR220 (EPC9126HC)           |
| 21   | 4        | R2, R3, R5, R6               | Resistor 3.9 k, 1% 0402  | Panasonic               | ERJ-P08J392V   |
| 22   | 1        | R24                          | Resistor 200, 1%, 0402   | Stackpole               | RMCF0402FT200R   |
| 23   | 1        | R25                          | Resistor 402, 1% 0402  | Stackpole               | RMCF0402FT412R   |
| 24   | 1        | R27                          | Resistor 820, 1% 0402  | Stackpole               | RMCF0402FT806R   |
| 25   | 1        | R29                          | Resistor 1.60 k, 1% 0402   | Stackpole               | RMCF0402FT1K60   |
| 26   | 1        | R31                          | Resistor 3.24 k, 1% 0402   | Stackpole               | RMCF0402FT3K24   |
| 27   | 2        | R33, R34                     | Resistor 953 1% 0402   | Panasonic               | ERJ-2RKF9530X  |
| 28   | 2        | R4, R19                      | Resistor, 1 k, 1%, 0603  | Vishay                  | PHP00603E1001BST1  |
| 29   | 5        | R7, R8, R21, R22, R23        | 100 1% 0402  | Panasonic               | ERJ-2RKF1000X  |
| 30   | 4        | R9, R26, R28, R32            | 10 1% 0402   | Panasonic               | ERJ-2RKF10R0X  |
| 31   | 1        | S1                           | DIP switch, 6 pos SPST, SOIC   | Nidec Copal Electronics | CHS-06TA   |
| 32   | 6        | TP1, TP2, TP3, TP4, TP5, TP6 | SMD probe loop   | Keystone                | 5015   |
| 33   | 1        | U1                           | LDO, 5.0 V 250mA DFN   | Microchip               | MCP1703T-5002E/MC  |
| 34   | 1        | U2                           | Laser  | User supplied           | User Supplied  |
| 35   | 2        | U3, U5                       | UHS dual buffer  | Fairchild               | NC7WZ16L6X   |
| 36   | 1        | U4                           | Gate driver  | Texas Instrument        | LMG1020  |

**Table 5: Optional Components**

| Item | Quantity | Reference | Part Description     | Manufacturer  | Part Number   |
|------|----------|-----------|----------------------|---------------|---------------|
| 1    | 2        | D1, D2    | User selected        | User selected | User selected |
| 2    | 1        | R20       | Resistor 100 1% 0402 | Panasonic     | ERJ-2RKF1000X |
| 3    | 1        | R30       | Resistor 0 1% 0402   | Panasonic     | ERJ-2GE0R00X  |

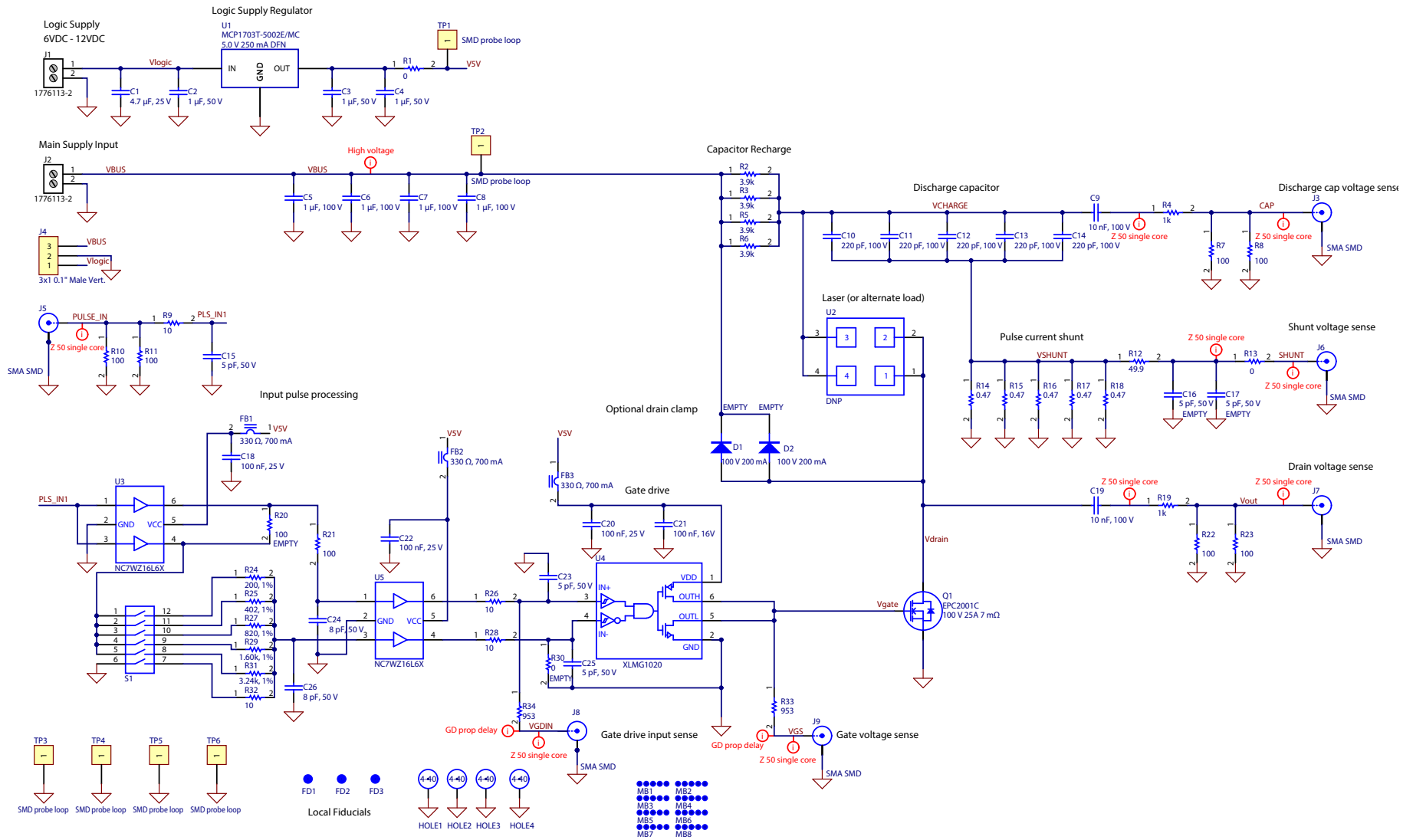


Figure7: Lidar Pulse Demonstration Board schematic

## For More Information:

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### Demonstration Board Notification

**The EPC9126xx board is intended for product evaluation purposes only. It is not intended for commercial use nor is it FCC approved for resale.** Replace components on the Evaluation Board only with those parts shown on the parts list (or Bill of Materials) in the Quick Start Guide. Contact an authorized EPC representative with any questions. This board is intended to be used by certified professionals, in a lab environment, following proper safety procedures. Use at your own risk.

As an evaluation tool, this board is not designed for compliance with the European Union directive on electromagnetic compatibility or any other such directives or regulations. As board builds are at times subject to product availability, it is possible that boards may contain components or assembly materials that are not RoHS compliant. Efficient Power Conversion Corporation (EPC) makes no guarantee that the purchased board is 100% RoHS compliant.

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