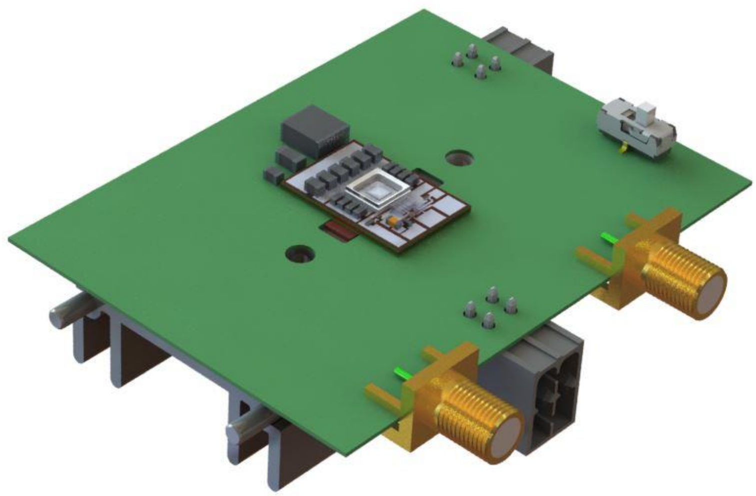
Vixar Application Note

VCSEL Evaluation Module
Quick Start Guide



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VCSEL Driver Module - Quick Start Guide

1 Description

The Vixar driver module is a multi-layer ALN ceramic SMT printed circuit board with bottom side solder pads. It was developed to produce short laser pulses at high optical power for Time of Flight (ToF) and emerging VCSEL flash LIDAR applications. It combines a high power VCSEL die with an ultrafast Gallium Nitride (GaN) Field Effect Transistor (FET), FET gate driver, and a discharge capacitor bank. The module can be driven for high speed pulsed operation and it can produce optical pulses of peak power up to 80 W. The small 11.5 mm x 17.0 mm driver module provides a very high-power density per unit area and requires adequate thermal management and heat sinking.

The laser is driven with an EPC2045 GaN switching FET that is capable of current pulses up to 130 A (300 us pulse width). The FET is driven with the Texas Instruments LMG1020 gate driver, a high current gate driver with propagation delays of 1 – 2 ns. Vixar has not measured the propagation delay for the overall module. For more information on the VCSEL die, the EPC2045 GaN FET, or the LMG1020 gate driver, please refer to the appropriate component datasheets.

The driver module is built with copper core PCB technology to improve thermal dissipation from the VCSEL and maximize laser performance. A large thermal bond pad is present for direct thermal dissipation from the VCSEL die to an attached heatsink. This thermal pad is electrically conductive to the VCSEL cathode (within the pulsed high current loop) and should not be connected to signal ground (GND). The thermal pad and heat sink can be connected to the system chassis ground. The system mother board should include a hole for direct connection to a heat sink.

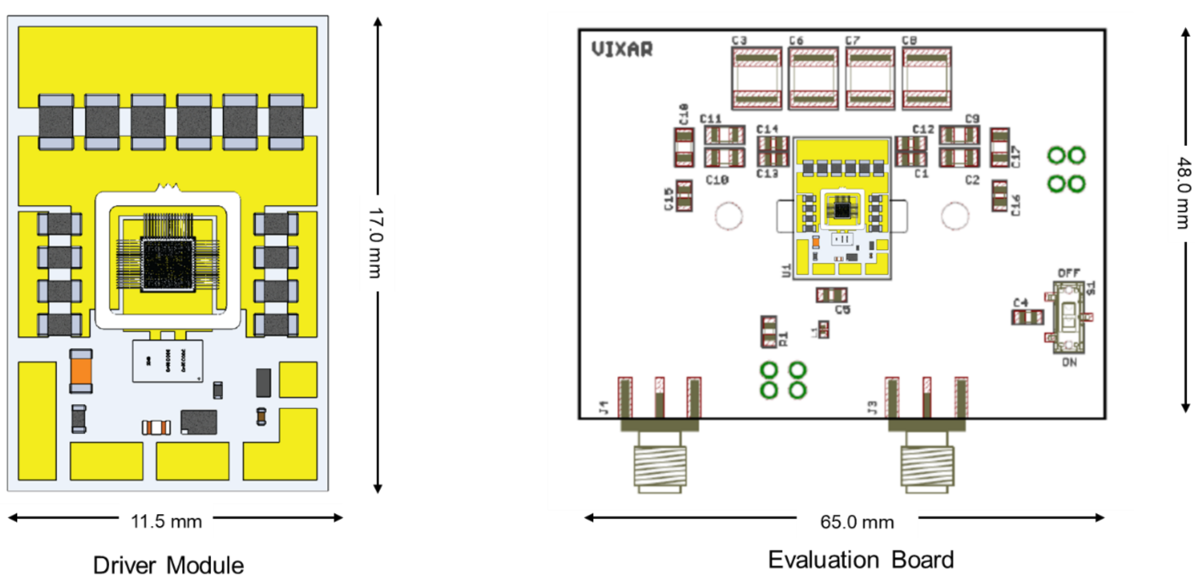

Figure 01: Vixar driver module (left) and evaluation mother board (right).

To make it simple and easy for our customers to test and evaluate the driver module, Vixar has developed a mother demonstration board with heat sink and mounted the module to the mother board. The module evaluation mother board is equipped with SMA connectors for the LVDS pulsed input signal and the output Timing Alignment (TAL) signal. The TAL signal is intended to be used to synchronize the TOF camera. The evaluation board is also equipped with additional capacitors to improve charge delivery to the driver module for higher duty cycle operation. An on/off enable switch is implemented to allow the FET and associated optical output to be turned on/off by the system. For example, this enable feature could be used by the system as part of the laser safety fault protection or for other system level uses.

2 Operating Principle

The basic operating principle of the driver module is to discharge stored electrical charge in capacitors through the laser diode when the GaN FET switch is ON. The capacitor bank (C_{Bank}) supplies instantaneous current to improve pulse rise time of the optical pulse. The capacitor bank is needed to support long pulses (up to 100 nsec) and burst mode pulse operation with thousands of pulses emitted at up to 1.5% burst mode duty cycle.

The VCSEL pulsed current level is controlled by the V_{dd} supply voltage applied to the capacitor bank and VCSEL anode. The gate driver is a special component designed to deliver enough current to the gate of the GaN FET switch that controls the current flow through the VCSEL. When LVDS V_{in} goes high, the FET turns on and current flows through the VCSEL. When LVDS Vin goes low, the FET turns OFF.

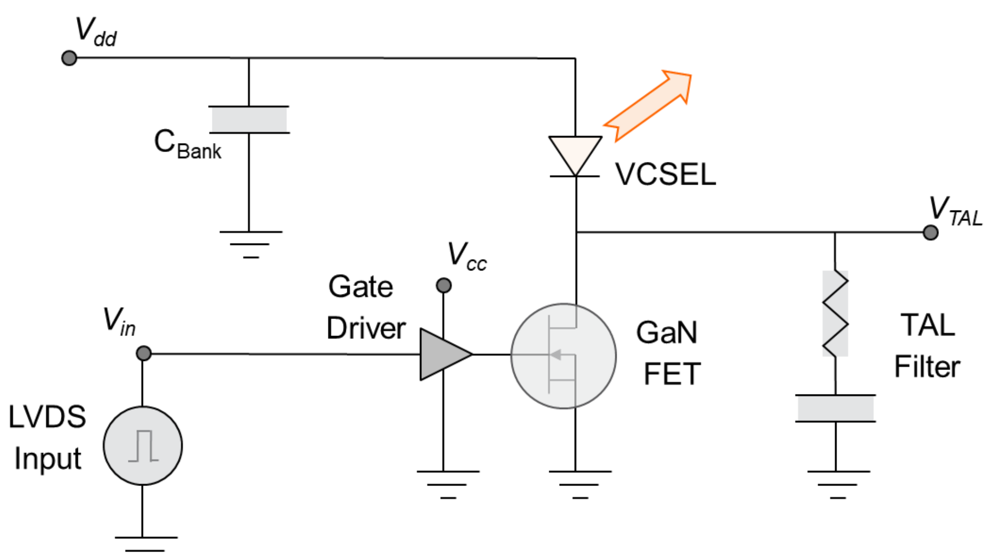

Figure 02: Circuit illustration of the driver module.

The driver module is equipped with a single large 4.0 mm^2 VCSEL die. This VCSEL die is designed with bond pads to reduce the wire bond loop inductance and improve the uniformity of the emission across the large VCSEL. The Vixar driver module utilizes wire bonds around 3 sides of the die allowing for direction connection of the VCSEL cathode to the GaN FET. The driver module wire bonds and multi-layer PCB design was optimized to reduce the FET switch loop inductance, essential for short rise times in high power pulses.

The module comes installed with either the 850nm (V00133) and 940nm (V00132) VCSEL die product currently available from Vixar's standard portfolio. For more information on the VCSEL die, please refer to their respective datasheets.

3 Quick Start Guide

The evaluation board is easy to set up to test the performance of Vixar's high power VCSEL driver module. The maximum VCSEL pulse current is controlled by adjusting the supply voltage (V_{dd}), typically set to 7V to 10V. The module also needs a stable 5V power supply voltage (V_{cc}) to power the gate driver. The V_{dd} and V_{cc} power connectors utilize quick connect power connectors. Vixar will provide the power supply mating connectors that include a screw terminal for connection to the power supply wires. The power supply wires should be twisted pairs to reduce noise. The V_{dd} power connectors have 2X V_{dd} and 2X gnd connections to allow for the use of two twisted pair connections to the power supply that may be needed to handle the high average current, typically about 2 amps.

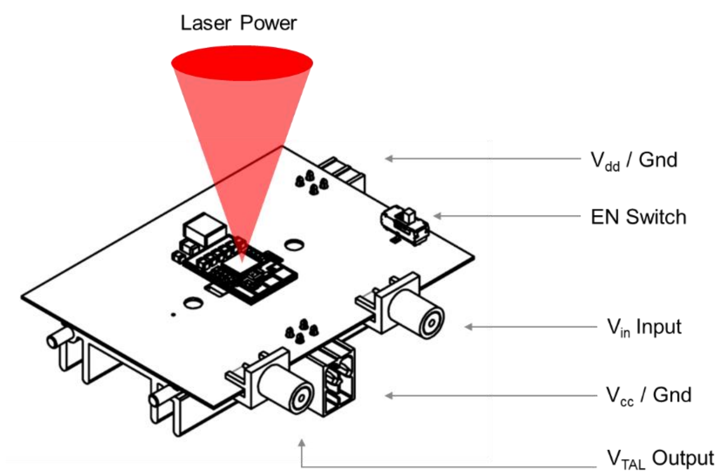

Figure 03: Connections for VCSEL evaluation board.

The VCSEL pulse width and duty cycle are controlled by the pulse width and duty cycle of the pulses applied to the LVDS input (V_{in}) SMA connector. The module also includes an SMA output connector for the Timing Alignment (TAL) to measure the voltage at the GaN FET drain and VCSEL cathode   to signal when current flow occurs. The motherboard has an enable switch to enable or disable the FET switching current and the associated optical output power.

The following procedure describes a step-by-step process to connect and evaluate the evaluation board equipped with the driver module:

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, connect the 5V logic supply V_{cc} and ground.
3. With power off, connect the VCSEL power supply to V_{dd} and ground. GND.
4. With power off, connect the signal pulse generator to the LVDS V_{in} SMA connector. This pulsed input is designed for a 5 V logic.
5. With power off, set the Enable switch to the OFF position.
6. Optional: Connect the TAL output V_{TAL} to an oscilloscope, using 50 Ω cables and with the scope input set to 50 Ω impedance.
7. Turn on the 5V power supply.
8. Turn on the pulse generator.
9. Turn on the V_{dd} power supply and set it to 8V.
10. Set the Enable switch to the on position and optical pulses should now be emitted.
11. An alternative power up sequence would be to leave the enable switch ON, then power up the module in this order:
    a. Turn on the pulse trigger source with specific pulse conditions.
    b. Turn on the logic supply voltage V_{cc} and set to a 5 V input.
    c. Turn on the driver module supply and slowly increase the voltage V_{dd} up to the target value to hit the target VCSEL current. For example, setting V_{dd} to 8 V will deliver around 100 A of peak VCSEL current.
12. Set up the electro-optical test assembly for laser power analysis. This may include a fast photodetector for optical pulse shape measurement and/or an integrating sphere for average light power measurement (see next section on Measurement Considerations).
13. While in operation, do not touch any portion of the module or evaluation board.
14. Once operational, adjust the bus voltage, input pulse width, and duty cycle (DC) as desired within the operating range and observe the system behavior.
15. A decrease in optical power will be measured when the VCSEL current, pulse length, and/or duty cycle are increased past a certain limit. This transition from increasing to decreasing optical power is known as the thermal rollover point, and the evaluation board should not be driven for extended periods at or beyond the thermal rollover point.
16. For shutdown, please follow steps 11a, 11b, and 11c, in reverse.

4 Measurement Considerations

The optical pulse is measured with a high-speed photodetector with sub-ns resolution. High-speed photodiodes have a small collection area to improve sub-ns resolution and thus cannot collect all the VCSEL output. The measurement only provides pulse shape and does not measure peak power output.

In addition, VCSEL transient modes cause the VCSEL's beam profile to shift when current starts to flow through the laser. This will impact optical pulse readings using a small area photodetector. It is highly recommended to use a diffuser in front of the VCSEL to average the modal transient response of the VCSEL.

The VCSEL peak power is inferred from measurements obtained by average optical power measured using an integrating sphere. The pulse waveform obtained from the fast photodetector is integrated and analyzed to determine peak power calculated from measured peak shape. The optical peak power should be measured over many pulses to have a more stable and accurate reading. An integrating sphere that has a large detector for average power measurements and a small detector for pulse shape and rise/fall measurements can be used.

The module was measured to exhibit 80W of peak power when driven with a V_{dd} = 8V and pulsing conditions of 50ns with 1% DC. The response time of photodetector shows a pulse rise time of ~10 ns that is relatively independent of supply voltage (V_{dd}).

An SMA connector is provided on the evaluation board for GaN FET drain voltage (V_{TAL}) measurements. The V_{TAL} measurement shows the voltage drop across the FET as a function of increasing VCSEL sink current. The voltage across the FET increases in higher driving currents, which results in lower wall plug efficiencies for the evaluation board at higher driving currents.

5 Typical Driver Module Performance Data

The peak optical power scales linearly with increasing VCSEL current. Measurement results have reported over 80 W of peak optical power for a 50ns 1% DC pulse with minimal evidence of thermal rollover at room temperature. Wall plug efficiency (WPE) of the driver module was calculated using average power, average current, and known supply voltage. WPE peaks at low currents (10A) and decreases with increasing higher supply voltages and VCSEL currents.

Changing the driving conditions of the evaluation board will impact the thermal load on the VCSEL die. Increasing pulse widths and duty cycles will increase the VCSEL junction temperature during operation and decrease wall plug efficiency. The VCSEL will degrade in slope efficiency (SE) and experience thermal rollover at a specific current based on these driving conditions. It's important to ensure the VCSEL is not driven near or above the thermal rollover current to ensure the laser doesn't experience accelerated aging or catastrophic failure.

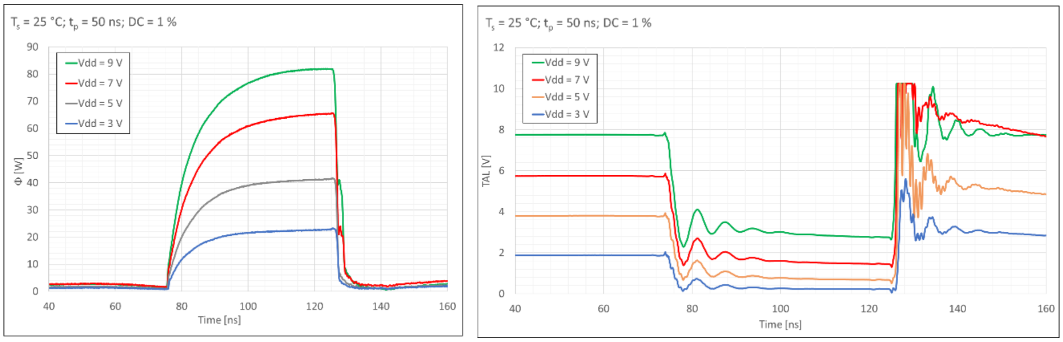

Figure 04: Measurement results for optical pulse power (left) and TAL voltage (right).

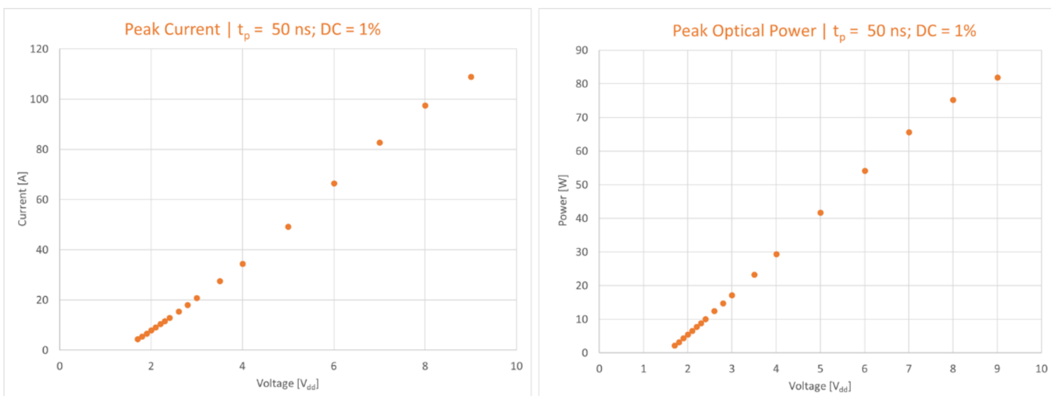

Figure 05: Measurement results for peak current (left) and peak optical power (right) as a function of supply voltage.

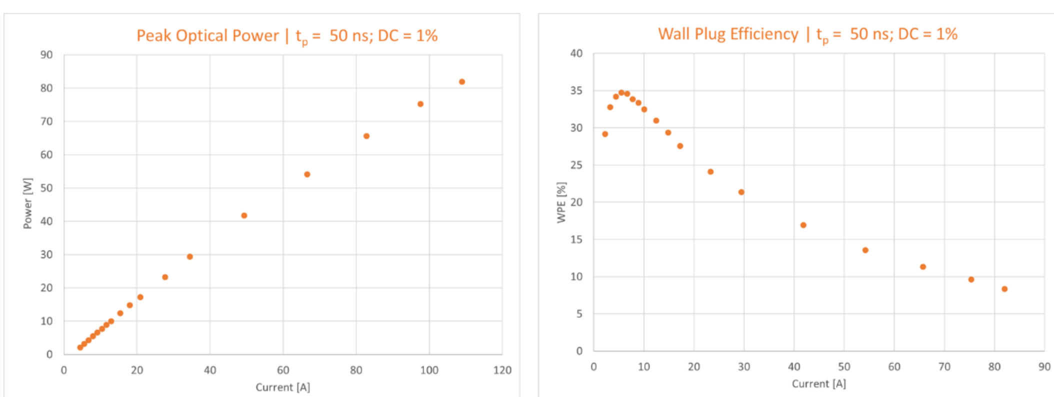

Figure 06: Measurement results for peak optical power (left) and driver module wall plug efficiency (right) as a function of peak current.

6 Laser Safety Considerations

The VCSEL driver module is a powerful product with a lot of flexibility in terms of driving conditions. While many evaluation boards on the market are limited to short ns pulse widths at low duty cycles, this module can theoretically be driven at continuous wave (CW) operation. This module can produce a non-diffused optical beam with >10 W of optical power during CW (100% DC) operation.

This level of laser power under these conditions puts the driver module at a Class 4 laser safety product. Personnel operating the driver module must be trained on laser safety and aware of the laser beam pulse conditions and trajectory. Physical damage may occur on both eye and skin tissue if directly exposed to the beam. Eye tissue damage may also occur from diffuse reflections of the laser beam if exposed over long periods. The laser module should not be connected and operated until users have chosen and worn the appropriate personal protection equipment (PPE).

7 Conclusions

The Vixar Driver Module and demonstration board were developed to assist customers in their VCSEL development for Time of Flight (ToF) applications. The module can be driven for high speed pulsed operation with high optical pulses up to 80 W of peak power. The driver module is built on a Copper PCB to improve thermal dissipation from the VCSEL. The module can be used to evaluate Vixar's high power VCSEL products over a wide range of testing conditions.

The driver module can be mounted on an evaluation board to for quick setup and measurement of Vixar's high power die with a simplified high-speed GaN FET circuit. SMA connectors allow quick connections for pulse triggers and FET voltage measurements. The module has shown to deliver 80W of peak optical power with 110 A of forward current.

Appendix A – Schematics

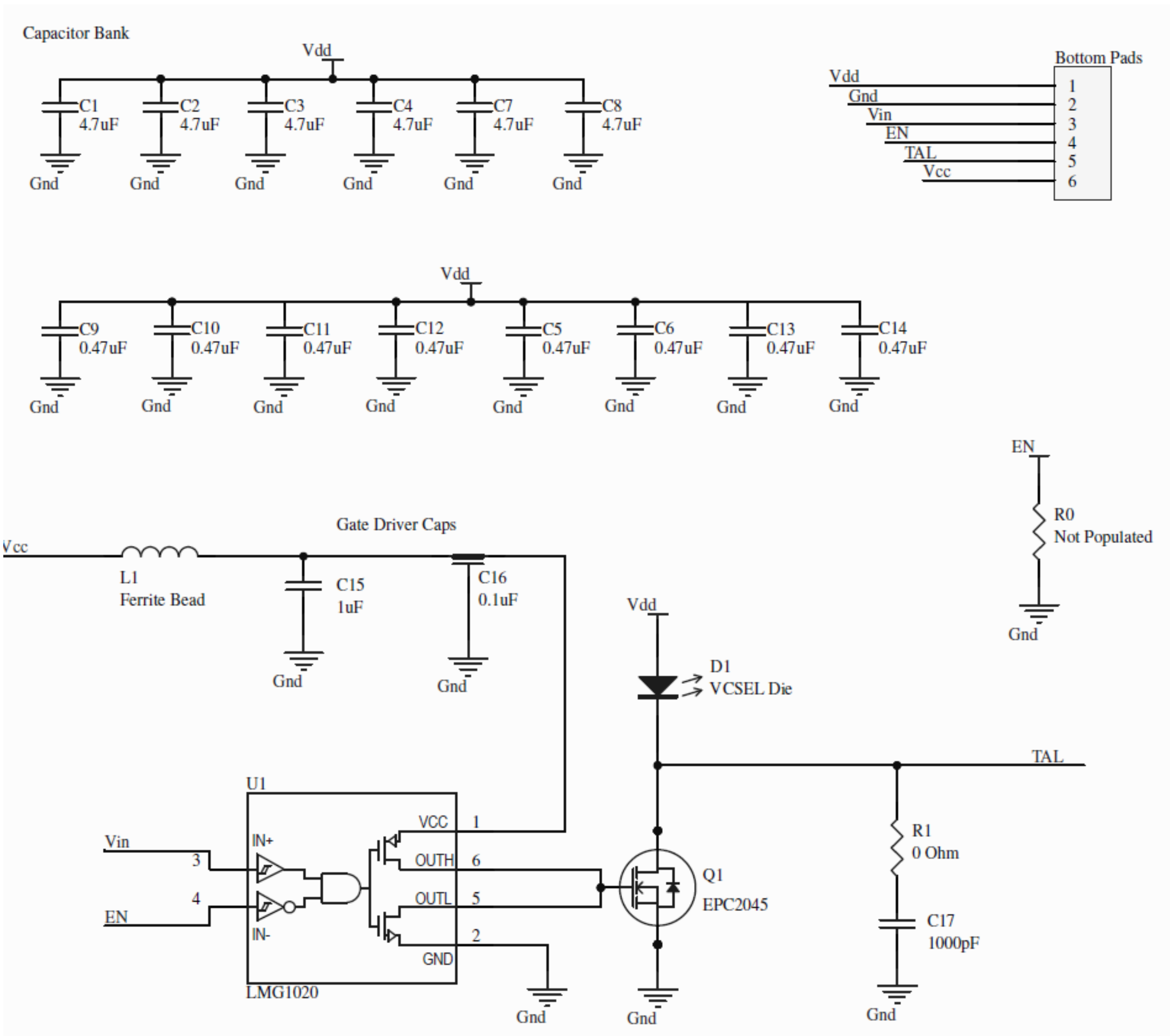

Figure 07: Schematic of the VCSEL driver module.

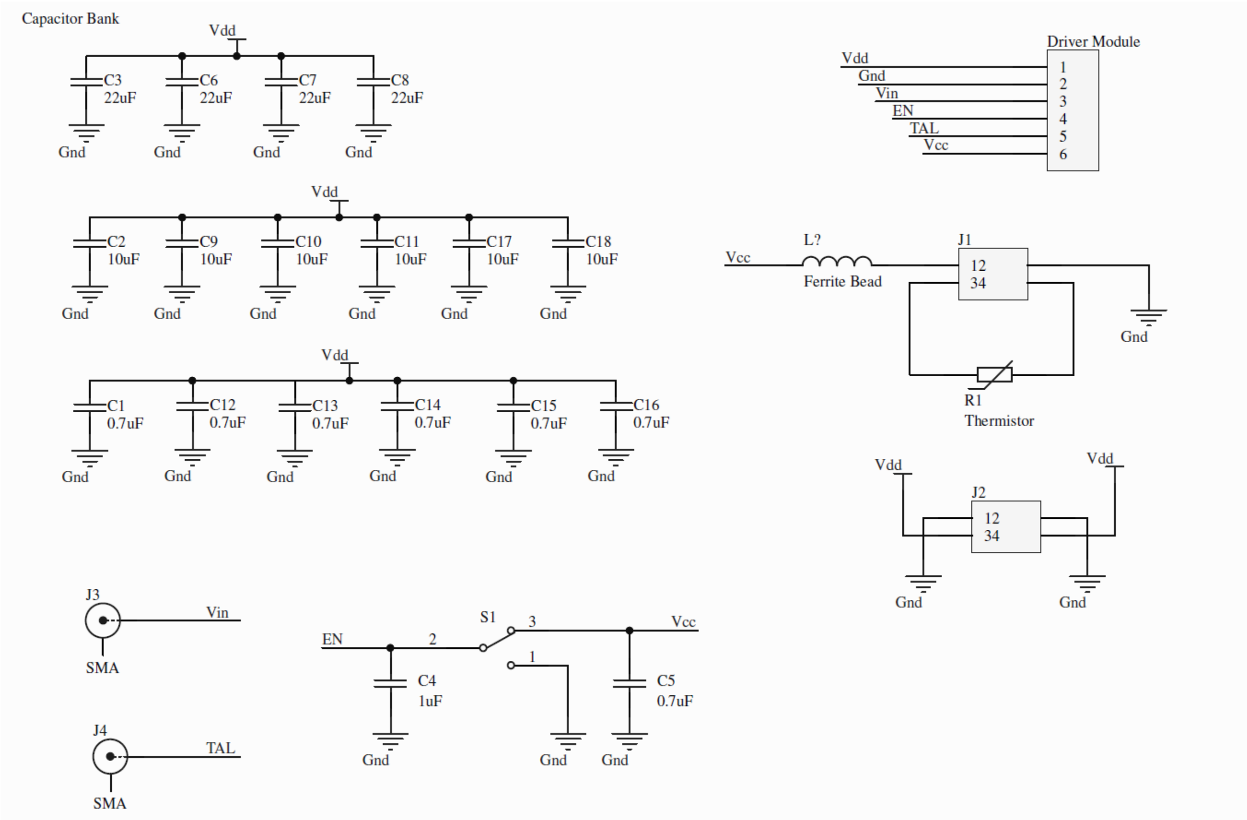

Figure 08: Schematic of the VCSEL evaluation board.