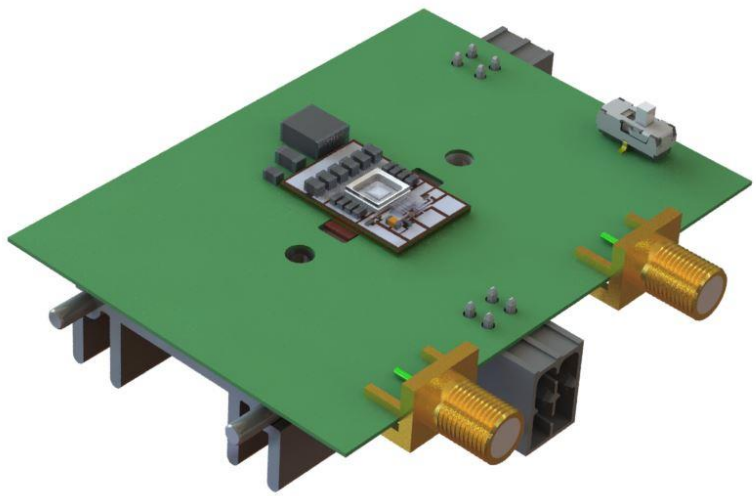
Vixar Application Note

VCSEL Evaluation Module
Quick Start Guide



Contents

1 Description

The Vixar evaluation module is developed to produce short laser pulses at high optical power for Time of Flight (ToF) and VCSEL flash LIDAR applications. It combines a high power VCSEL die with an ultrafast Gallium Nitride (GaN) Field Effect Transistor (FET), a gate driver, and a discharge capacitor bank. The module can be driven for high speed pulsed operation and it can produce short optical pulses of high peak power.

The evaluation module comes installed with either the 850 nm (V00133) and 940 nm (V00132) VCSEL die product currently available from Vixar's standard portfolio. The VCSEL is driven with an EPC2045 GaN switching FET that is capable of current pulses up to 130 A. The FET is driven with the Texas Instruments LMG1020, a high current gate driver with propagation delays of 1 – 2 ns. Please refer to the appropriate component datasheets for more information on the VCSEL die, the EPC2045 GaN FET, and the LMG1020 gate driver.

The driver circuit is built with 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 the attached heatsink. The driver circuit and evaluation board are both equipped with capacitor banks to improve charge delivery to the driver circuit for higher duty cycle (DC) operation.

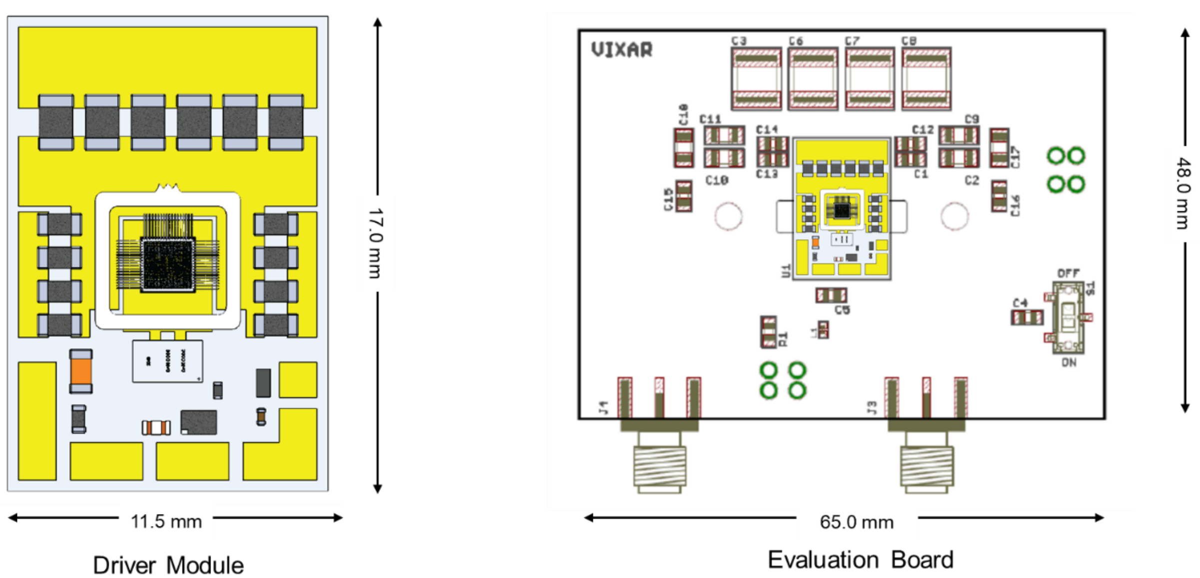


Figure 01: VCSEL driver circuit (left) and evaluation module (right).

2 Operating Principle

The driver circuit utilizes stored electrical charge in capacitors to power the laser diode when the GaN FET switch is ON. The capacitor bank (C_{Bank}) supplies instantaneous current to improve pulse rise time in the optical signal. The amount of charge that determines the VCSEL peak current is controlled by the V_{dd} supply voltage applied to the capacitor bank and VCSEL anode. The large capacitor bank is also needed to support long pulse trains with thousands of pulses emitted at high burst mode duty cycles.

The evaluation module's PCB design and assembly were optimized to reduce the FET switch loop inductance, essential for short rise times to achieve short pulse widths at low voltages. The driver module is equipped with a single large 4.0 mm^2 VCSEL die designed with bond pads to reduce the wire bond loop inductance and improve the uniformity of the emission across the large VCSEL. The gate driver is also essential to swiftly deliver charge to the gate of the GaN FET switch that controls the current flow through the VCSEL. When V_{in} goes high, the FET turned on by the gate driver and current flows through the VCSEL to produce optical power.

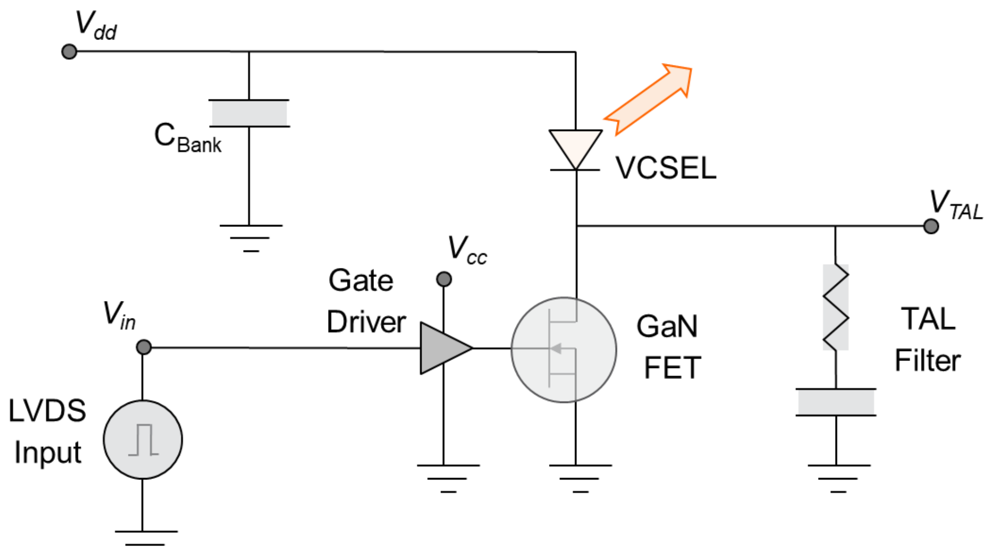


Figure 02: Circuit illustration of the driver module.

3 Quick Start Guide

The evaluation board is easy to set up to test the performance of Vixar's high power VCSEL die. The maximum VCSEL pulse current is controlled by adjusting the supply voltage (V_{dd}), typically set between 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 from Phoenix Contact (Part #: 1790108). The power supply lines should be twisted pairs to reduce noise. The V_{dd} power connectors should have wire connections that can handle the high average currents depending on the desired operation mode.

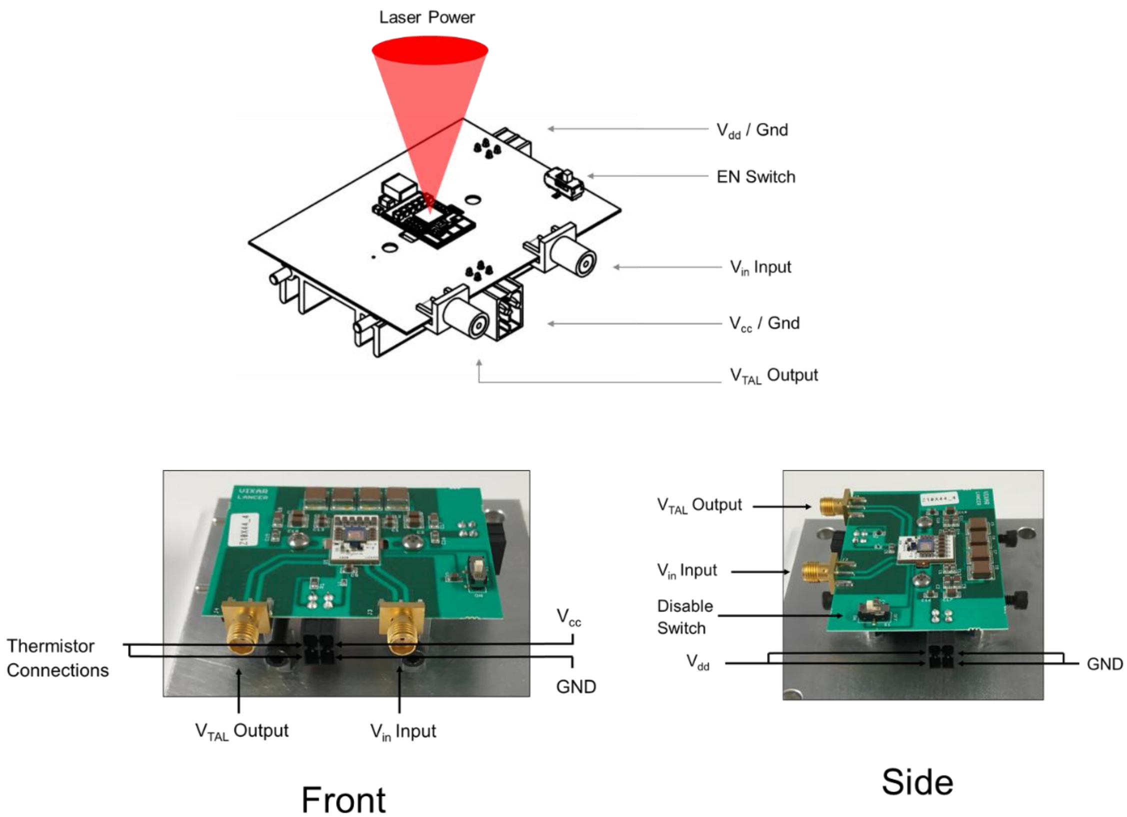


Figure 03: Connections for VCSEL evaluation board.

The VCSEL pulse width and duty cycle are controlled by the voltage applied to the input (V_{in}) SMA connector. The module also includes an SMA output connector for the Timing Alignment (TAL) to measure the voltage drop at the GaN FET drain to signal when current flow occurs. The motherboard has a disable switch to deactivate the gate driver and inhibits current flow through the VCSEL die.

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 [see later section on Laser Safety Considerations].
2. Before any connections, set the Disable switch to the ON position.
3. With power off, connect the 5V logic supply V_{cc} and GND [J1].
4. Optional: The J1 connection point also has leads to the on-board thermistor for temperature measurements.
5. With power off, connect the VCSEL power supply to V_{dd} and GND [J2].
6. With power off, connect an external signal pulse generator to the V_{in} SMA connector. This pulsed input is designed for a 5 V logic.
7. Optional: Connect the TAL output V_{TAL} to an oscilloscope, using 50 Ω cables and with the scope input set to 50 Ω impedance.
8. 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].
9. Turn on the V_{cc} power supply and set it to 5V.
10. Turn on the V_{dd} power supply and set it to 2V. This is enough forward voltage to allow VCSEL lasing operation at a low forward current.
11. Turn on the pulse generator and set the Disable switch to the OFF position. Optical pulses should now be detected by a high speed photodetector.
12. While in operation, do not touch any portion of the module or evaluation board.
13. After verifying that the VCSEL is operational, the bus voltage, input pulse width, and duty cycle can be adjusted as desired within the safe operating limits.
14. A decrease in optical power will be measured when safe operating limits (VCSEL current, pulse length, and/or duty cycle) are exceeded. 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. Rollover within a single pulse can also be inferred from power droop in the pulse shape and should also be avoided.
15. For shutdown, please follow steps up to 11 in reverse.

4 Measurement Considerations

The high speed 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 quantified 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.

The module is measured to exhibit ~80 W of peak power when driven with a V_{dd} = 8V and pulsing conditions of 50 ns with 1% DC. The response time of photodetector shows a pulse rise time of ~15 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 50 ns 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.

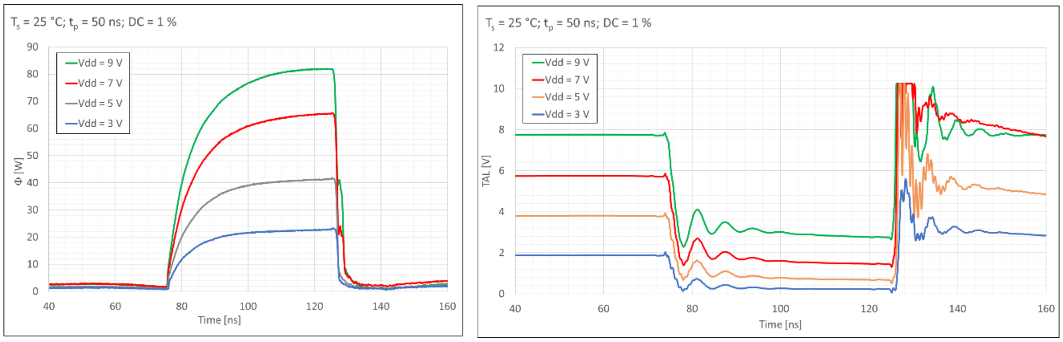


Figure 04: Measurement results for optical pulse power (left) and TAL voltage (right).

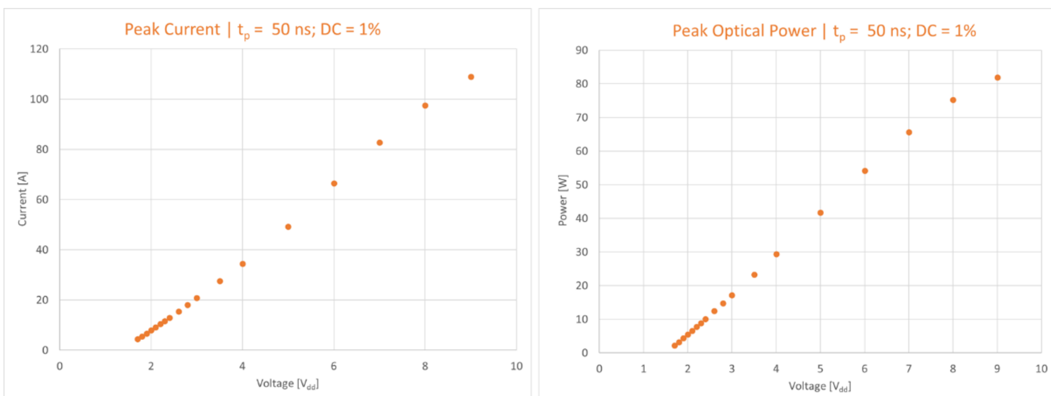


Figure 05: Measurement results for peak current (left) and peak optical power (right) as a function of supply voltage.

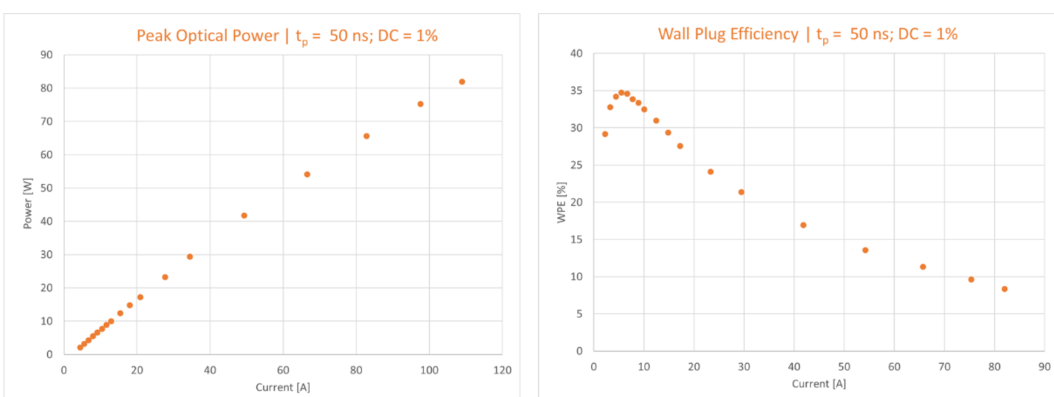


Figure 06: Measurement results for peak optical power (left) and driver module wall plug efficiency (right) as a function of peak current.

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 using PCB technology 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

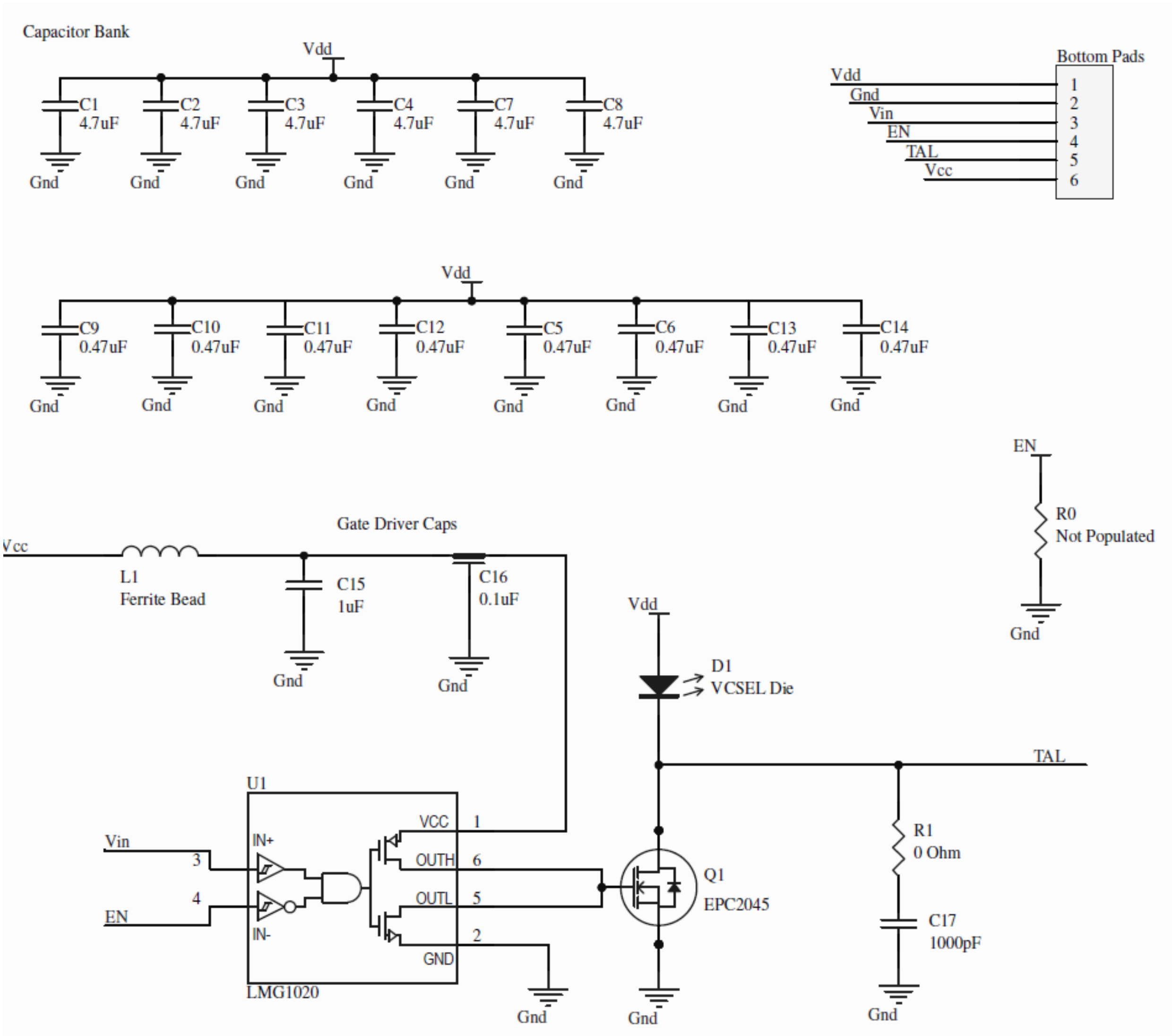


Figure 07: Schematic of the VCSEL driver module.

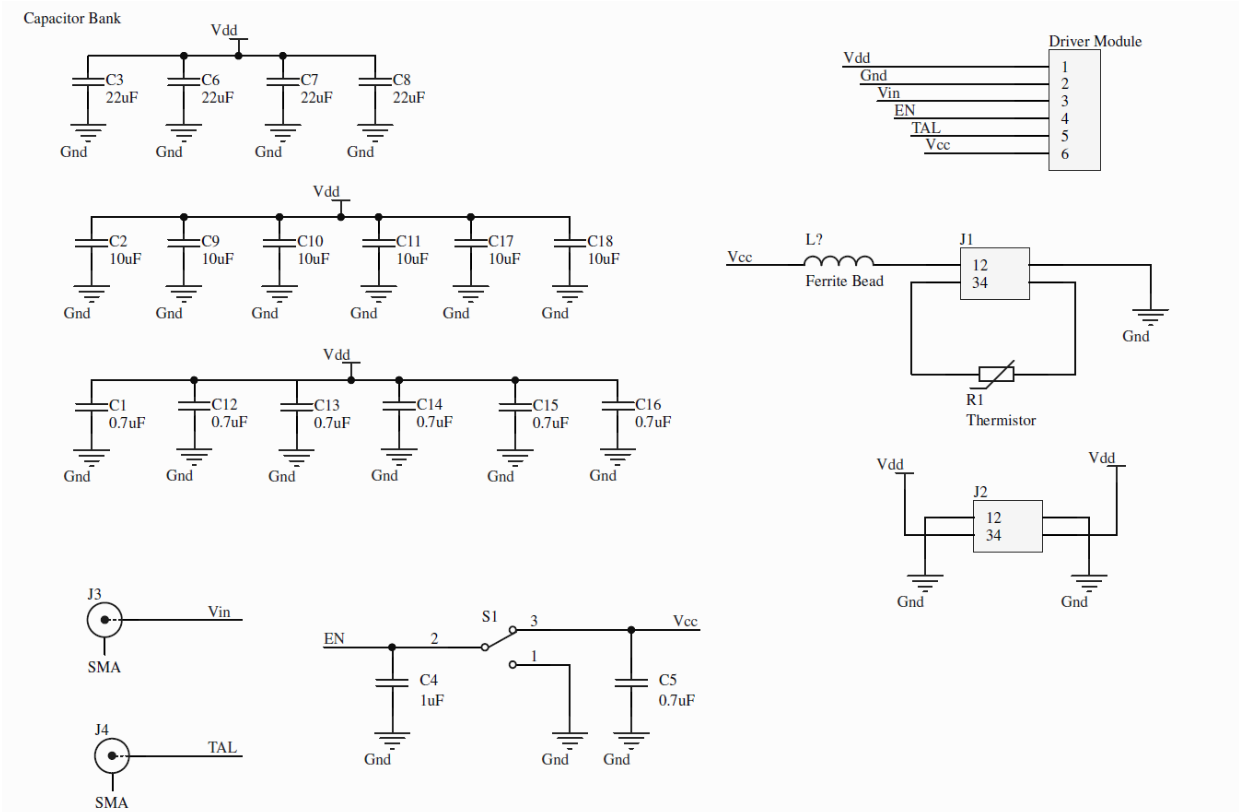


Figure 08: Schematic of the VCSEL evaluation board.