Application Note

HV Gate Driver Design

APN-0001 March 2025 v2.0

Gate Description for MEMS Switches

Menlo MEMS switches are ohmic MEMS devices that are controlled by a gate as shown in Figure 1 below. The gate voltage determines the switch state; the switch closes or turns ON when the gate is at a high voltage (VBB) and opens or turns OFF when the gate is near zero volts. Gate drivers for MEMS typically require high voltage (> 60 V) but low current (< 10 nA) outputs.

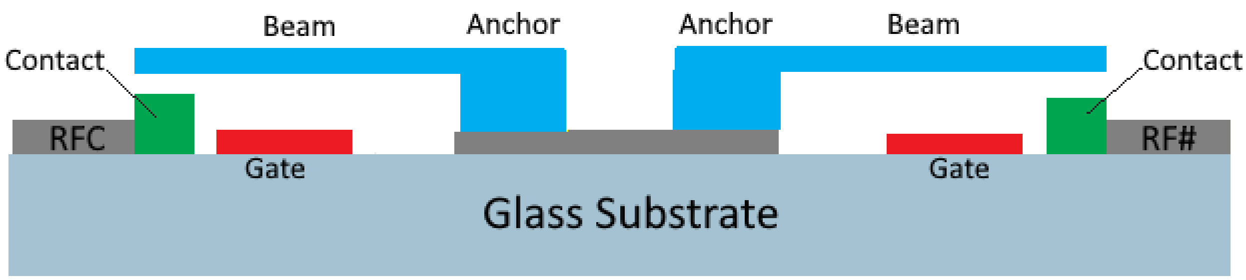

Figure 1: Cross-Section Diagram of MEMS Switch

Gate control signals are typically sourced from a DC-DC boost converter, such as an inductive switching regulator or capacitive charge pump. When controlling a switch from a microcontroller or other low-voltage device, a high-voltage (HV) driver is also required to level translate low-voltage control logic levels to high-voltage gate signals.

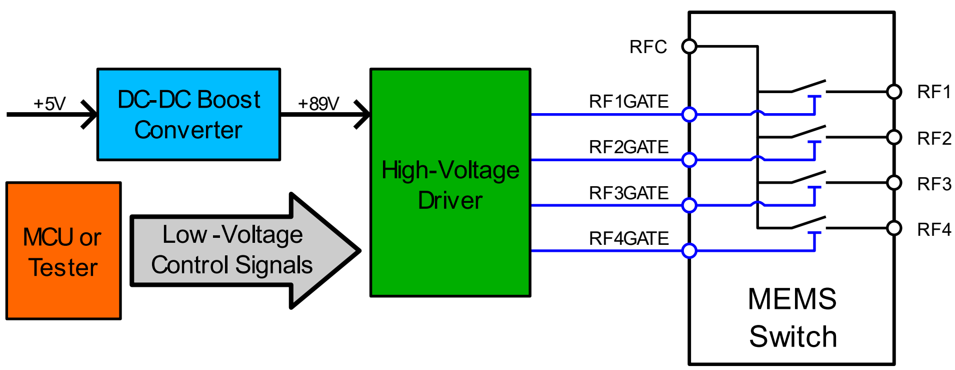

Figure 2: Functional Block Diagram for a MEMS Switch Driver

Menlo Components with Internal Gate Drivers

An example of a Menlo device that integrates the necessary VBB source and HV driver is the MM5120, as shown in Figure 3. The charge pump uses a +5V supply to generate VBB (+89 V), and the HV driver applies VBB to each MEMS gate when instructed to by the digital core.

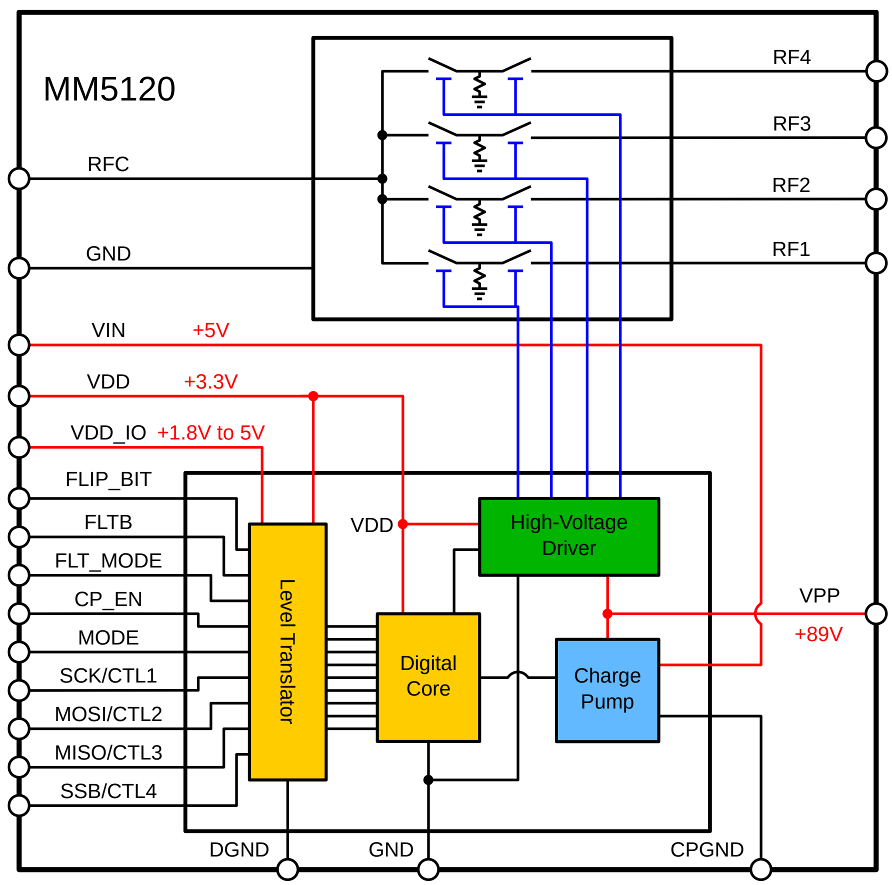

Figure 3: MM5120 with Integrated Charge Pump and HV Driver

MEMS switches with integrated drivers simplify design and reduce footprint size for applications using a small number of MEMS switches. In applications using dozens or hundreds of switches per system, it may be more efficient to use a single boost converter combined with a separate HV driver circuit to drive all switch gates.

Design Considerations for External Gate Drivers

Gate driver control should satisfy all datasheet specifications for the connected MEMS devices. A non-comprehensive list of gate specifications is listed below.

Absolute Maximum and Minimum Gate Voltage

The gate driver circuits should be designed to never exceed the absolute maximum or minimum specifications, even in non-operational situations. Care should be taken to avoid hot-plugging and other transient voltage spikes on gate lines in systems where the driver is on a separate board from the MEMS device.

High and Low Gate Voltage Levels

Driver circuits should be designed to always comply with high and low voltage levels in operational situations. Ensure the tolerance of the boost converter output does not exceed the MEMS gate voltage tolerance.

As an example, the gate voltage range for MM5130-03NDB is seen below.

Parameter	Minimum	Typical	Maximum	Unit
Gate Bias Voltage (V_{BB})	87	89	91	V_{DC}

Figure 4: MM5130-03NDB Specification (Rev 2.8)

To design a VBB source for this product, it's common to use a DC-DC boost converter with a feedback topology like the one below. Choosing R1 = 1 MΩ and R2 = 9.1 kΩ will set VOUT/VBB to 88.7 V nominally.

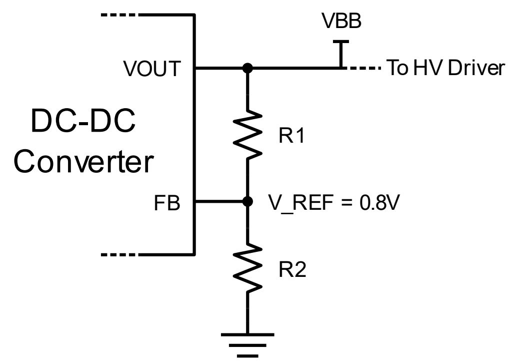

Figure 5: Common DC-DC Boost Converter Feedback Circuit

For this feedback circuit, low-tolerance resistors are required for R1 and R2. Do not use resistors with 5% tolerance as these can result in ±4.4 V variation in VBB, which falls outside the Gate Bias Voltage minimum and maximum requirements. Choose 0.1% tolerance for feedback circuit resistors.

Supply Current/Load Resistance

Boost converters should be capable of supplying the maximum current draw of the HV driver without voltage droop or thermal failure. This current draw is dependent on the HV driver design and parasitic resistive loads on the HV driver output. Current draw from MEMS gates is typically negligible (<10 nA per device).

Slew Rate

HV drivers must comply with slew rate specifications in the low-to-high and high-to-low transitions of the gate voltage. Failure to meet slew rate specifications can result in reduced cycle lifetime and switching time that degrades from cycle-to-cycle. Slew rate is typically measured in Volts per microsecond, and can be calculated using the formula below:

$$SR = \frac{\Delta V}{\Delta t}$$

- SR = Slew Rate in V/µs
- ΔV = Voltage difference between 10% and 90% of gate voltage in V
- Δt = rise or fall time between 10% to 90% of gate voltage in µs

When using a current-controlled HV driver, such as the MM101, the slew rate can be calculated using the formula below:

$$SR = \frac{I_{HV}}{C_L}$$

- SR = Slew Rate in V/µs
- I_{HV} = HV driver sink/source current in µA
- C_L = Load Capacitance in pF

When using the MM101, two outputs can be tied together to double the sink and source current, therefore doubling the slew rate. See Figure 6 for an example circuit diagram.

Noise Considerations

Proper filtering should be used on the boost converter output to avoid switching noise from affecting RF noise figure performance, and boost converters should not be placed directly adjacent to MEMS switches. See the circuit diagrams in DC-DC Boost Converters for more information.

MEMS switches with integrated charge pumps like the MM5120 will have elevated noise figure due to proximity between the RF pins and the charge pump. For any application that has a maximum noise figure requirement, disable the internal charge pump and supply the VBB voltage from one of the recommended DC-DC Boost Converters (see MM5120 Datasheet or other relevant datasheet for implementation details). Alternatively, use MEMS switches without internal driver circuits like the MM5130 combined with one of the external driver circuits listed later in this document.

MM101 External Gate Driver

The MM101 is an ideal solution for applications using less than 20 MEMS devices per system. The MM101 is a complete DC-DC boost converter and HV driver solution, and is capable of driving two SP4T MEMS switches. The internal DC-DC boost converter is a charge pump that operates with a 5V source and can generate an 80V or 90V source. The internal HV driver can operate with either serial (SPI) or low-voltage parallel (GPIO) inputs to generate 8 HV outputs.

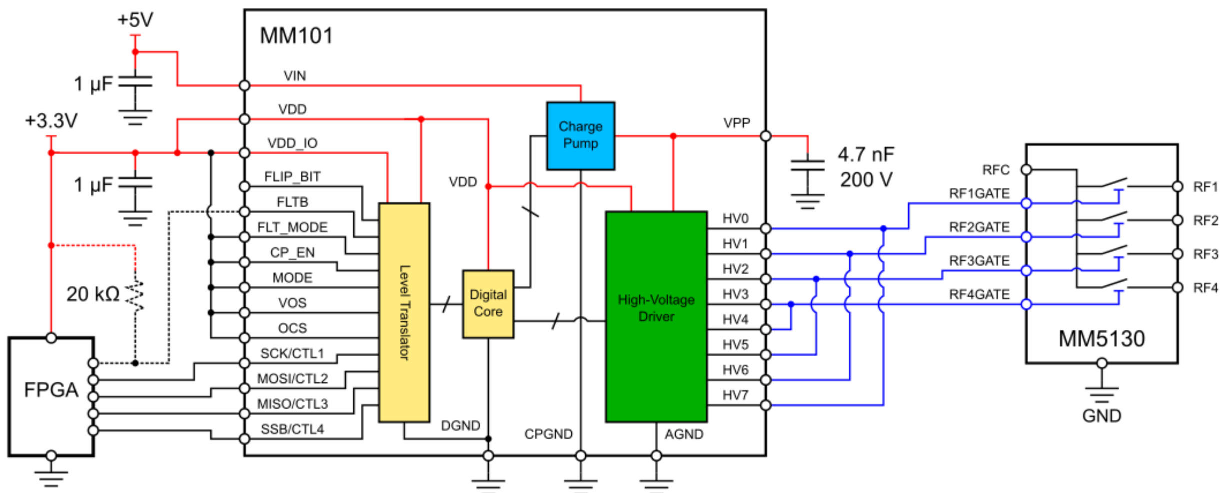

Figure 6: MM101 Circuit Diagram to Drive MM5130

When designing with the MM5130 and the MM101, place them as close as possible to minimize the trace capacitance between the two devices. Reducing the capacitance will increase the driver's slew rate. Outputs can also be tied together to multiply the slew rate. See the MM101 datasheet and contact Menlo for further details and design support.

Other External Gate Drivers

For applications using more than 20 MEMS devices per system, Menlo recommends a two-chip solution that uses one DC-DC boost converter circuit combined with one or more HV driver circuit(s). These solutions can drive hundreds of MEMS devices with a smaller total footprint compared to solutions using many switches with internal drivers, or many MM101 devices.

DC-DC Boost Converters

LT3482

For an external DC-DC boost converter, Menlo recommends the LT3482 from Analog Devices. Note APD is used as the voltage source instead of VOUT2.

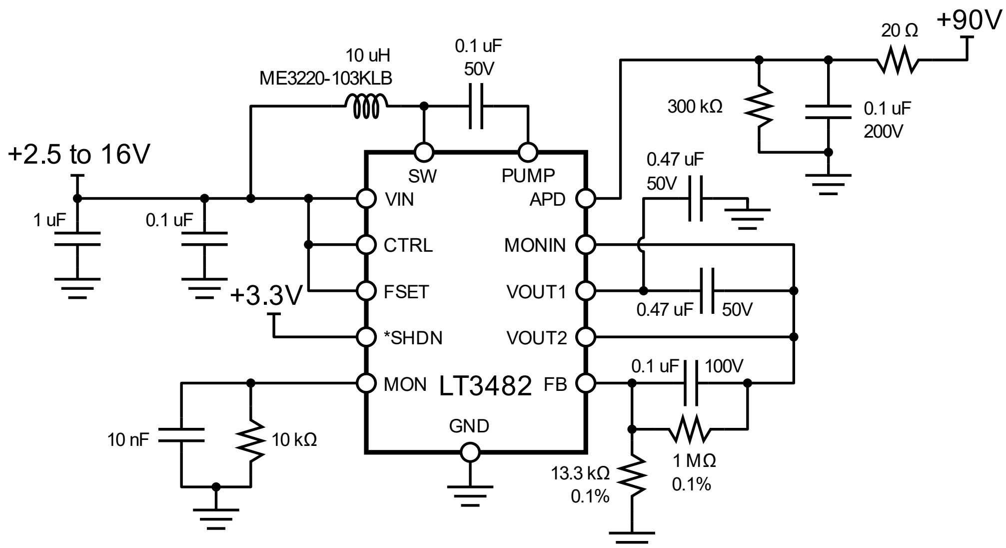

Figure 7: LT3482 Recommended Circuit for a +90V Source

Menlo's evaluation of the resulting VBB regulation over a range of resistive loading conditions is plotted below in Figure 8 as example guidance. To avoid VPP voltage droop, total load resistance should be greater than 100 kΩ.

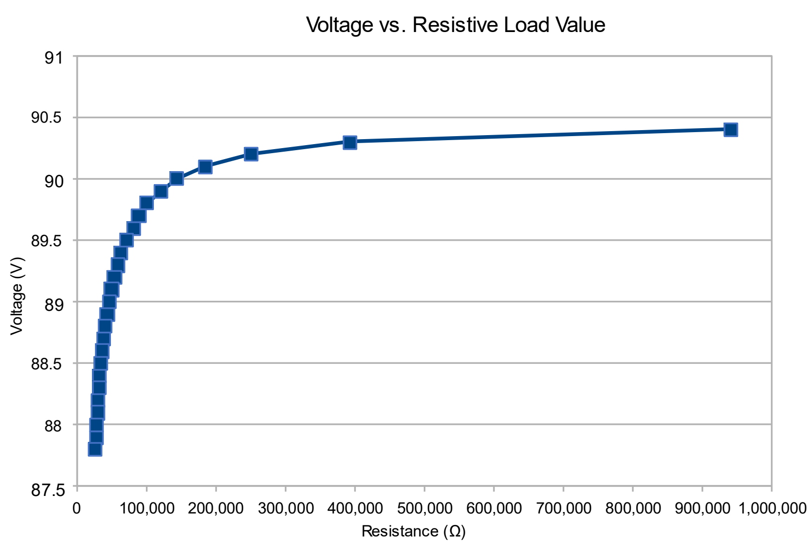

Figure 8: APD Output Voltage vs Resistive Load for LT3482 Circuit

High-Voltage Drivers

Discrete HV Gate Driver

Open-drain HV driver circuits made with discrete transistors are recommended for applications switching more than 20 MEMS devices in parallel. Figure 9 below shows an example of a single N-channel MOSFET driver circuit translating low voltage logic signal SW to the high voltage VBB level. RP is the pull-up resistor, and CS is the parasitic capacitance of all MEMS gates and the PCB traces.

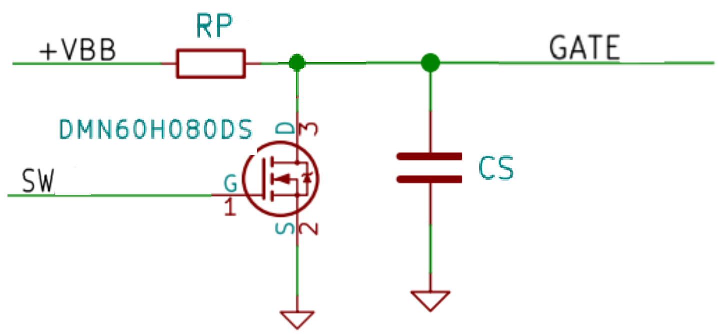

Figure 9: Open-Drain MOSFET HV Driver Circuit

This circuit is capable of driving hundreds of MEMS device gates in parallel by tying the GATE output to one RFGATE# pin on every MEMS. The transistor is an inverter such that SW needs to be near zero volts to turn off the MOSFET and thereby allow the GATE voltage to rise to VBB through the VBB pull-up resistor RP and turn on the MEMS switch. Other component values and transistors (including BJTs like the FMMT495TA) can be implemented.

The resistor RP should be chosen carefully: a large value increases the GATE rise time while a low value increases current draw from +VBB. The worst-case current load occurs when all MEMS switches are off and each transistor sinks current through their corresponding pull-up RP. When using four discrete open drain driver circuits with LT3482, choose an RP value greater than 500 kΩ.

Serial-to-Parallel HV Gate Drivers

Serial-to-parallel HV driver chips are ideal for applications with more than 20 MEMS devices that must be controlled independently. Menlo recommends the following HV driver chips from Microchip:

- HV513: 8-Channel S-P Converter, w/Push-Pull Outputs, 250V
- HV509: 16-Channel S-P Converter, w/Push-Pull Outputs, 250V
- HV7620: 32-Channel Serial to Parallel Converter w/ Push Pull Output, 200V

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