Overview

There are two types of Mirrorcle MEMS Drivers: **Digital input (with SPI inputs)** and **Analog Input (Bias Differential Quad-channel, with two analog inputs)**. Both drivers convert low-voltage user inputs into two differential pairs of high voltage analog outputs. These compact drivers include programmable 5th order low-pass filters (default) or 2nd order continuous time low-pass filters (option for larger quantities) for smoothing of the output voltages. These MEMS drivers are designed and optimized for the driving of Mirrorcle Technologies’ quasistatic, resonant-quasistatic, and resonant MEMS mirrors.

Dimensions approx.: 35mm x 40mm x 9.3mm
Features

- Low voltage supply and low power consumption (<100mW)
- Four high voltage output channels (two biased differential pairs) (~0V up to 200V)
- Embedded regulated DC/DC converter creates high voltage supply from the +5VDC supply (VDD)
- Four embedded Bessel low pass filters. User-provided clock sets cut-off frequency for all four LPFs with separate control for X and Y axis.
- (Optional for larger quantities) Four continuous time low pass filters.
- Small form factor, approximately ½ of a credit card size
- Power supply monitoring with auto-shutdown
- Bandwidth up to 25kHz (governed by the user-set LPFs)
- Analog Input – Two analog inputs for X and Y axis drive (+/- 10V)
- Digital Input – SPI digital inputs for X and Y axis drive (3VTTL)
All dimensions are in mm
Dimensions approx.: 35mm x 40mm x 9.3mm

Connector stands out 4mm from edge of PCB

3.68
5.00

1.55 mm

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Driver Serial Number (S/N) Format

Driver S/N Format:
Analog Input: A#### - #
Digital Input: D#### - #
Letter A or D followed by at least 4-digit number.

Final letter designation for driver output range:
B: 160V, Vbias = 80V
T: 180V, Vbias = 90V
X: 200V, Vbias = 100V

Example: A2500 – T
MEMS Driver – Analog Input, with 180V driver output range (Vbias = 90V)

On backside of PCB
Design Version:
D## for Digital Input
A## for Analog Input
Example: D52
Driver Output Range Types

- Different MirrorcleTech MEMS Mirrors products may have different required or recommended driving voltage ranges to achieve best performance.

- The lowest-voltage driving range or category is “Boost 160” or B160 which has following specs:
  - $V_{bias} = 80V$, $V_{difference} = -160V$ to $160V$

- The **typical driving range or category is “Turbo 180” or T180** with specs:
  - $V_{bias} = 90V$, $V_{difference} = -180V$ to $180V$

- The next category is “eXtreme 200” or X200 with specs:
  - $V_{bias} = 100V$, $V_{difference} = -200V$ to $200V$

- The **Analog Input MEMS Driver** has preset Range since the driver contains the Bias Differential Quad-channel circuit, where the bias cannot be adjusted.

- The **Digital Input MEMS Driver** is typically X200 Range, providing the user to utilize the full voltage range since to set any $V_{bias}$ and $V_{difference}$ since all 4 output channels are set via software.
Part Name, Numbering and Range

- To accommodate driving the different MirrorcleTech MEMS Mirrors products to achieve best performance, there are a few different options available:
  - **MEMS Driver – Analog Input** is a simpler interface, with three different voltage ranges, B160, T180 and X200 (T180 being the most recommended). These drivers require the user to provide a ±10V input for the X and Y axis, which corresponds to the Vdifference of the output range of the specific driver. For example, a T180 driver would correspond ±10V with a 0-180V Vdifference, about a Vbias of 90V. The maximum voltages should be checked with the specific device before operation, to prevent any damage to the device.
  - **MEMS Driver – Digital Input** are only recommended for advanced development kit users who have already used the Mirrorcle hardware, and understand the methodology of driving the device directly with all four channels. In this case, the user is required to generate the Biased-Differential-Quad channels correctly. The user is also responsible for setting the correct Vbias and Vdifference limitations, to not damage the device.

<table>
<thead>
<tr>
<th>Driver Name</th>
<th>Board Version</th>
<th>Interface</th>
<th>Output Range</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEMS Driver - Digital Input</td>
<td>5.4 RevB</td>
<td>Digital SPI</td>
<td>0-200V (X200)</td>
<td>DR-10-056-00</td>
</tr>
<tr>
<td>MEMS Driver - Analog Input</td>
<td>5.4 RevB</td>
<td>±10V Analog Inputs</td>
<td>0-160V (B160)</td>
<td>DR-11-054-00</td>
</tr>
<tr>
<td>MEMS Driver - Analog Input</td>
<td>5.4 RevB</td>
<td>±10V Analog Inputs</td>
<td>0-180V (T180)</td>
<td>DR-11-055-00</td>
</tr>
<tr>
<td>MEMS Driver - Analog Input</td>
<td>5.4 RevB</td>
<td>±10V Analog Inputs</td>
<td>0-200V (X200)</td>
<td>DR-11-056-00</td>
</tr>
</tbody>
</table>
## J1: Input Connector Pinout and Functions

### MEMS Driver - Analog Input

<table>
<thead>
<tr>
<th>J1-Pin</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>XIN</td>
<td>Analog Input X (XIN)</td>
</tr>
<tr>
<td>2</td>
<td>YIN</td>
<td>Analog Input Y (YIN)</td>
</tr>
<tr>
<td>3</td>
<td>+5V</td>
<td>VDD (+5VDC)</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>5</td>
<td>EN</td>
<td>MEMS Driver Output Enable</td>
</tr>
<tr>
<td>6</td>
<td>N/C</td>
<td>No Connection</td>
</tr>
<tr>
<td>7</td>
<td>N/C</td>
<td>No Connection</td>
</tr>
<tr>
<td>8</td>
<td>N/C</td>
<td>No Connection</td>
</tr>
<tr>
<td>9</td>
<td>FCLK_X</td>
<td>Filter Clock for X-Axis (60x filter cut-off)</td>
</tr>
<tr>
<td>10</td>
<td>FCLK_Y</td>
<td>Filter Clock for Y-Axis (60x filter cut-off)</td>
</tr>
</tbody>
</table>

Mating Cable Socket for J1: – Digikey Part ID: SAM8218-ND
J1: Input Connector Pinout and Functions

<table>
<thead>
<tr>
<th>J1-Pin</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N/C</td>
<td>No Connection</td>
</tr>
<tr>
<td>2</td>
<td>N/C</td>
<td>No Connection</td>
</tr>
<tr>
<td>3</td>
<td>+5V</td>
<td>VDD (+5VDC)</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>5</td>
<td>EN</td>
<td>MEMS Driver Output Enable</td>
</tr>
<tr>
<td>6</td>
<td>SDI</td>
<td>SPI Data for AD5664R (DIN)</td>
</tr>
<tr>
<td>7</td>
<td>SYN</td>
<td>SPI Sync for AD5664R (SYNC_)</td>
</tr>
<tr>
<td>8</td>
<td>SCK</td>
<td>SPI Clock for AD5664R (SCLK_)</td>
</tr>
<tr>
<td>9</td>
<td>FCLK_X</td>
<td>Filter Clock for X-Axis (60x filter cut-off)</td>
</tr>
<tr>
<td>10</td>
<td>FCLK_Y</td>
<td>Filter Clock for Y-Axis (60x filter cut-off)</td>
</tr>
</tbody>
</table>

Mating Cable Socket for J1: – Digikey Part ID: SAM8218-ND
## J2: Output Connector Pinout and Functions

<table>
<thead>
<tr>
<th>J2-Pin</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HV_A (X+)</td>
<td>MEMS Channel X+</td>
</tr>
<tr>
<td>2</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>3</td>
<td>HV_B (X-)</td>
<td>MEMS Channel X-</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>5</td>
<td>HV_C (Y-)</td>
<td>MEMS Channel Y-</td>
</tr>
<tr>
<td>6</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>7</td>
<td>HV_D (Y+)</td>
<td>MEMS Channel Y+</td>
</tr>
<tr>
<td>8</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>9</td>
<td>N/C</td>
<td>No Connection</td>
</tr>
<tr>
<td>10</td>
<td>N/C</td>
<td>No Connection</td>
</tr>
</tbody>
</table>

Mating Cable Socket for J2: – Digikey Part ID: SAM8219-ND
# LED Definitions

In active operation of a MEMS driver, following 3 LEDs should all be ON:

<table>
<thead>
<tr>
<th>LED Color</th>
<th>ON Status</th>
<th>OFF Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>+5VDC Power Supply</td>
<td>Power is OFF</td>
</tr>
<tr>
<td>Red</td>
<td>MEMS Driver Enabled: User set EN to HIGH and provided adequate VDD supply.</td>
<td>MEMS Driver disabled.</td>
</tr>
<tr>
<td>Blue</td>
<td>FCLK_Y** clock running (correct use) or HIGH</td>
<td>FCLK_Y is LOW</td>
</tr>
</tbody>
</table>

*Blue LED dims at Filter Clock (FCLK) frequencies > 100kHz

**Only one FCLK is verified by LED, but both must be provided in standard use.
# Electrical Specifications - Inputs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Supply</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>VDD</td>
<td>4.85</td>
<td>5</td>
<td>5.2</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Supply Current</td>
<td>$I_{DD}$</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>mA</td>
<td>MEMS Driver Disabled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>mA</td>
<td>MEMS Driver Enabled</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>(100mA transient pulses at start up)</em></td>
</tr>
<tr>
<td><strong>Logic Inputs – Digital Pins</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Low Voltage</td>
<td>$V_{INL}$</td>
<td>-</td>
<td>0.2</td>
<td>0.4</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Input High Voltage</td>
<td>$V_{INH}$</td>
<td>2.7</td>
<td>3</td>
<td>-</td>
<td>V</td>
<td>See Max High voltage for digital pins below</td>
</tr>
<tr>
<td>MEMS Driver Enable</td>
<td>EN</td>
<td></td>
<td>5</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Digital SPI</td>
<td>SDI, SCK, SYN</td>
<td></td>
<td>3.3</td>
<td>5</td>
<td>V</td>
<td>Refer to AD5664RB0RZ-3 datasheet and Appendix A for more information.</td>
</tr>
<tr>
<td>Filter Clock Voltage</td>
<td>FCLK_X, FLCK_Y</td>
<td></td>
<td>3.6</td>
<td>5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td><strong>Filter Clock</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filter Clock Frequency</td>
<td>FCLK_X, FLCK_Y</td>
<td></td>
<td>3</td>
<td>-</td>
<td>3000 kHz</td>
<td>Filter Clock input frequency based on MEMS datasheet recommendation.</td>
</tr>
<tr>
<td><strong>Analog Inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X and Y analog inputs</td>
<td>XIN, YIN</td>
<td>-10</td>
<td>0</td>
<td>10</td>
<td>V</td>
<td>Refer to Appendix B</td>
</tr>
<tr>
<td>XIN and YIN input impedance</td>
<td>XIN, YIN</td>
<td>80.6</td>
<td></td>
<td></td>
<td>k Ohm</td>
<td>Effective, to opamp virtual ground</td>
</tr>
</tbody>
</table>

*Note: Power supply should be capable of at least 100mA current to avoid start-up failure. In OEM applications, a capacitor of at least 100uF is recommended at Vdd/GND supply before the MEMS Driver to accommodate.*
## Electrical Specifications - Outputs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sym.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEMS Driver Output Range</strong></td>
<td>X+, X-, Y-, Y+</td>
<td>0.5</td>
<td>80</td>
<td>160</td>
<td>V</td>
<td>Refer to MEMS datasheet for maximum driving voltages of the MEMS device. (&lt;50pF load)</td>
</tr>
<tr>
<td>(B160)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MEMS Driver Output Range</strong></td>
<td>X+, X-, Y-, Y+</td>
<td>0.5</td>
<td>90</td>
<td>180</td>
<td>V</td>
<td>Refer to MEMS datasheet for maximum driving voltages of the MEMS device. (&lt;50pF load)</td>
</tr>
<tr>
<td>(T180)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MEMS Driver Output Range</strong></td>
<td>X+, X-, Y-, Y+</td>
<td>0.5</td>
<td>100</td>
<td>200</td>
<td>V</td>
<td>Refer to MEMS datasheet for maximum driving voltages of the MEMS device. (&lt;50pF load)</td>
</tr>
<tr>
<td>(X200)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MEMS Driver Bandwidth</strong></td>
<td></td>
<td>50</td>
<td>-</td>
<td>25000</td>
<td>Hz</td>
<td>Bandwidth limited by Low-Pass Filters. If LPFs are bypassed, max. bandwidth is 25kHz</td>
</tr>
</tbody>
</table>

- MEMS driver output has a low current output capability, <0.05mA, intended to drive open-circuit electrostatic MEMS
- Not intended for larger capacitive loads (<50pF/channel) or long cables
Setting up FCLK_X and FCLK_Y inputs

- User must provide filter clocks for the 5th order Bessel LPFs of both axes (FCLK_X and FCLK_Y). In standard uses, both are tied to the same clock.
- When either of those is not connected, or the clock is not running, output voltages do not update or follow the input.
- The pins can be driven by ~3.3V CMOS33/TTL signal, 50% duty cycle
- Set clock frequency to the desired filter cut off frequency x 60
  - E.g.: Device datasheet (on the right) states “Recommended LPF cut off freq” of 500Hz, then FCLK Input = 30kHz
  - In cases where advanced users require to bypass the LPFs, 3MHz may be applied for minimal filtering and group delay.
- Filter part: MAX7413

Device Parameters Summary

- Device ID: S31191
- Actuator Type: A7M20.2
- Actuator Mode: Gimbal-less Dual-Axis Quasistatic
- Mirror Type and Size: Integrated mirror of 2000um diameter
- Mirror Coating: Aluminum
- Maximum Mech. Angle - X Axis [degrees]: 4.9996
- Maximum Mech. Angle - Y Axis [degrees]: 5.1014
- Maximum Vdifference - X Axis [V]: 160
- Maximum Vdifference - Y Axis [V]: 159
- Driver Bias Voltage (Vbias) [V]: 80
- Resonant Frequency - X Axis [Hz]: 1340
- Resonant Frequency - Y Axis [Hz]: 1331
- Quality Factor - X Axis: 77
- Quality Factor - Y Axis: 76

**Recommended LPF Cutoff Frequency (6th Order Bessel) [Hz]: 500**

Example device datasheet shown above.
Driver Connections Breakout: BRK-DRIVER 5.x

- PCBA which breaks out the input connection side of both digital and analog-input MEMS driver to easy to use terminals or test points / pins. Each pin of the 10-pin connector has its own screw terminal, hook, and hole connection and easy to read label. **Not necessary for OEM uses, but recommended and prepared for first-time users** of Mirrorcle's MEMS Drivers (Ver. 5.x). A new user should consider purchasing this item with the first purchase of a MEMS Driver 5.x, digital- or analog-input type.

- **INPUT**: Screw terminals, test points, connect pins - multiple options for easy connections.

- **OUTPUT**: 10-pin header connector (0.05", 2 rows, right angle) which can be directly connected to MEMS Drivers (Analog and Digital) of 5.x generations.

- This item is only offered with a purchase of a Mirrorcle MEMS Driver
Breakout Board Mechanical Dimensions

All dimensions are in mm

Dimensions approx.: 49mm x 55mm x 14mm

J1 – Digikey Part ID: 1175-1627-ND

J2 – Digikey Part ID: ED2616-ND
TROUBLESHOOTING
Troubleshooting Basics

- In any development, experimentation, troubleshooting of the MEMS driver, no MEMS mirror should be connected to the output of the driver.
  - Users should plug in MEMS Mirror only after they have verified signals follow the desired commands on an oscilloscope, and
  - observe that all four channels follow the “BDQ Principle” (see section in this guide) with bias and differences not exceeding maxima (per device datasheet), with smooth transitions (no steps/impulses/sharp edges), and with correct setting of the on-board LPFs (per device datasheet).
  - When users change code or settings of their FPGA/MCU Controller which is connected to the MEMS driver, we recommend testing outputs on an oscilloscope first, before connecting a MEMS Mirror.
  - In some cases when the digital signals (FCLK, SPI) have very high slew rates and high frequencies, there is a potential for crosstalk and simultaneous switching noise among the signals. Using digital signals with reduced slew rates where possible should be considered.
- To ensure proper signals are provided to the MEMS driver we recommend troubleshooting with the Breakout PCB for easy probing of inputs.
LEDs blinking or not all ON when driving

- **Green LED** indicates the 5V Supply status. If the LED is off, there is no 5V supply to the driver. Note that the LED may be on even before adequate voltage is provided.

- **Blue LED** is intended to help users verify that FCLK input clocks are provided. Note that it is only connected to FCLK_Y, but both clocks are needed for standard operation.
  - This LED is generally more dim due to pulsed nature of the voltage and more dim at higher frequencies. It is only for guidance/reminder to users to provide clocks to filters.

- **Red LED** indicates MEMS Driver is enabled and fully powered.
  - LED is OFF: +5VDC should be above 4.85V and stable, EN should be HIGH
  - LED is blinking: Same as line above - the driver is not able to bring up the Vpp supply due to inadequate current or voltage provided to VDD.
    - +5VDC power supply limit should be >100mA to allow for any transient pulses during MEMS driver enable. Alternatively, a capacitor of >100uF value should be at the Vdd / GND power supply input to the MEMS Driver.
No Movement of MEMS Mirror

- Unplug MEMS Mirror and probe the +5VDC, Enable and Vpp (voltage should be >200V) test points to verify the correct voltages on the driver for proper operation.

- Set driver inputs to be at Vbias, and measure the four driver output voltages to verify the driver operation.
  - If driver output voltages are not correct, probe Vref (Vref = 1.25V) to ensure the DAC is enabled correctly.

- If driver is working properly, connect the MEMS Mirror and repeat the measurements. If there is still no movement on MEMS Mirror, contact Mirrorcle Support: support@mirrorcletech.com
DRIVING THE MIRRORS - THE BDQ PRINCIPLE
The BDQ Principle - Overview

- Bias-Differential Quad-channel (BDQ) is the proper methodology for driving Mirrorcle MEMS Mirrors.
  - All four channels are biased to 80V (Vbias). This is MEMS mirror origin/rest position.
  - Pairs of channels apply (biased) differential voltages from ~0V to 160V. Mirror rotates approximately proportionally to the applied Vdifference for each axis.
    - Vdifference (X-axis) = HV_A – HV_B
    - Vdifference (Y-axis) = HV_C – HV_D
- All Mirrorcle control and driving hardware should be operated in this fashion and all Mirrorcle software supports this mode.
- In the **BDQ PicoAmp** it is inherently implemented by adding a bias to the four output channels and forcing them as differential pairs.
Bi-directional Driving with Unipolar Outputs

HV_B is high
HV_A is low
Vdifference(X) is negative so mirror rotates in X- direction

HV_A is high
HV_B is low
Vdifference(X) is positive so mirror rotates in X+ direction

Resulting X movement

Bi-directional driving with unipolar voltages. Direction depends on which portion of the rotator (X+ or X-) is driven with the higher voltage. As a result each axis can move from negative angle to positive angle from rest/normal position.
The BDQ Principle – Vbias and Vdifference

- Opposing actuator channels are given differential inputs operating at that bias. E.g. X+ channel 110V and X- channel 50V means X axis is driven by Vdifference of 60V at Vbias of 80V.

- Each command for each axis of the MEMS mirror is therefore comprised of Vbias and Vdifference setting where Vbias is constant (80V) and Vdifference is such that a desired angle is obtained. In the example below Vdifference of +100V can be applied to obtain +3.3° of rotation about the X axis.

![Graph showing mechanical mirror tilt vs. DC voltage difference](image)
Axes Orientation and Sign of Vdifference

- **X+ and Y+ mirror rotation** is defined by the rule of (right-hand) thumb, based on the x and y axes as shown.

- **X Axis:**
  - $V_{\text{difference}}(X) > 0$ results in $X+$ rotation about the x-axis
  - $V_{\text{difference}}(X) < 0$ results in $X-$ rotation about the x-axis

- **Y Axis:**
  - $V_{\text{difference}}(Y) > 0$ results in $Y-$ rotation about the y-axis
  - $V_{\text{difference}}(Y) < 0$ results in $Y+$ rotation about the y-axis

- Typically, MirrorcleTech MEMS mirrors are mounted so that X-axis driving provides laser beam sweep in the horizontal plane.
APPENDIX A: SPECIFIC INSTRUCTIONS
FOR MEMS DRIVER – DIGITAL INPUT
Initialization of DAC (AD5664R)

1. Set up DAC. Following the AD5664R DAC datasheet*, we recommend the following initialization sequence which must be run by the master controller which communicates commands to the PicoAmp on every power up of the PicoAmp. The sequence is to reset the DAC, turn on its internal reference, enable all 4 channels, and set up for software loading.
   
   - 2621441 Decimal or 0x280001 to command FULL RESET
   - 3670017 Decimal or 0x380001 to command ENABLE INTERNAL REFERENCE
   - 2097167 Decimal or 0x20000F to command ENABLE ALL DAC CHANNELS
   - 3145728 Decimal or 0x300000 to command ENABLE SOFTWARE LDAC

2. After the above sequence, user can check whether the DAC is ready and the commands were successfully loaded into registers if the internal reference comes up to 1.25V. This is pin 10 of the DAC, labeled Vref. It is good to check this voltage at this point when debugging.

3. Now user can start streaming voltages commands to each channel. All development / debug should be performed without a MEMS device connected. Channels are assigned as follows:
   
   - DAC A goes to HV_A (X+)
   - DAC B goes to HV_B (X-)
   - DAC C goes to HV_C (Y-)
   - DAC D goes to HV_D (Y+)

4. User should verify that correct voltages are streaming at desired sample rate. There are four holes in the board before each of the LPFs where it is convenient to check DAC outputs. Minimum output is 0V for 16’h0000 (0x0000) and maximum output is 2.5V for 16’hFFFF (0xFFFF) input.

*Very often new users of the AD5664R DAC miss the details in its user guide, most notably that it is programmed by “negedge” clock (data is loaded on high to low transitions of the clock)
Vbias Settings

- Refer to page 1 of the device datasheet for the Bias Voltage (Vbias) values. The MEMS driver has a range from 0V-200V, corresponding to the DAC values of 0-65535. Those DAC values are a combination of Vbias and Vdifference digital values. Vbias digital value is computed as follows:
  - Vbias digital value = (Vbias/200) * 65535

Example, if a device datasheet states Vbias of 80V:
  - The Vbias digital value would be (80/200) * 65535 = 26214

*MEMS Driver circuit Gain tolerance of +/- 1.5%
The MEMS driver has a range from ~0V-200V, corresponding to the DAC values of 0-65535. VdifferenceMax sets the maximum Vdifference that will be applied to the MEMS mirror for any user input. The Max Vdifference and Vbias voltages refer to the device datasheet. It should be calculated as follows.

- VdifferenceMax digital value = \((\text{VdifferenceMax}/200) \times 65565\), where VdifferenceMax(Vdiff) is the maximum Vdifference allowed for the mirror per device datasheet.
- Vdifference range would be from \((\text{Vbias} - \text{Vdiff}/2)\) to \((\text{Vbias} + \text{Vdiff}/2)\)

Example, with Maximum Vdifference of 140V, and Vbias of 80V:

- VdifferenceMax digital value = \((140/200) \times 65535 = 45874\)
- The example device voltage range would be from: 3277 \((26214 - 45874/2)\) to 49151 \((26214 + 45874/2)\)

*MEMS Driver circuit Gain tolerance of +/- 1.5%
Bringing Up the Driver

Note: This sequence should be performed and verified the correct voltages are being output before connecting to an actual MEMS Device.

1. Power the Driver board by providing VDD (Pin 3) and GND (Pins 4) to J1.
2. Send the register setting sequence via SPI bus to Setup the DAC (See DAC initialization page). This will enable DAC’s internal reference and outputs.
3. After DAC is enabled, send the Vbias digital input (See Vbias settings page) values to all four channels of the DAC to set the MEMS device outputs to Vbias.
4. Set the FCLK frequency to control the filter cut-off (See FCLK settings page) per recommended settings for the MEMS mirror connected to the PicoAmp.
5. Enable the MEMS Driver outputs by sending a TTL High (3V to 5V) through Pin 5 on J1.
   
   WARNING: BEFORE ENABLING THE MEMS DRIVER OUTPUTS, ENSURE THAT THE VOLTAGE OUTPUT ON ANY CHANNEL WILL NOT EXCEED MAX VOLTAGE OF MEMS DEVICE PER THE DEVICE DATASHEET.
6. Now all MEMS Driver outputs X+, X-, Y-, Y+ should be at Vbias. MEMS mirror may move slightly to a new, ‘biased origin.’ This is the MEMS mirror’s zero position or origin.
7. PicoAmp is now ready to drive the MEMS mirror to new positions. Although signals are filtered, user should avoid discontinuous waveforms with large, abrupt steps or impulses.
8. When ready to plug in the MEMS device: MEMS mirrors should not be connected or disconnected when MEMS Driver Outputs are enabled. Therefore, disable the MEMS Driver (Pin 5 to GND), connect the MEMS device, and re-enable the MEMS Driver.
Applying Desired MEMS Drive Values

- Each MEMS mirror includes a characterization report (datasheet) in pdf and raw data form.
- Static Response characterization provides a reference for dependence of mech. angle on Vdifference for each axis. From these Vdifference values, XIN and YIN are simply calculated:
  - E.g. angle of the mirror needs to be +4.5° on both axes. From the graph we determine Vdifferences of ~135V.
  - \[ X_+ = 26214 + \left( \frac{135V}{200V} \right) \times 32767 \]
  - \[ X_- = 26214 - \left( \frac{135V}{200V} \right) \times 32767 \]
  - \[ Y_- = 26214 + \left( \frac{135V}{200V} \right) \times 32767 \]
  - \[ Y_+ = 26214 - \left( \frac{135V}{200V} \right) \times 32767 \]

Example of Static Response graph from a MEMS mirror datasheet:

Safe range of Vdifference for this example MEMS mirror. Exceeding these limits may damage the MEMS mirror.
Shutting Down the Driver

1. Send only Vbias digital input to all four channels to return the mirror to origin. (zero the Xnorm and Ynorm terms)
2. Disable the MEMS Driver by sending a Digital Low to Pin 5 on J1.
   WARNING: DO NOT DISABLE DIGITAL INPUTS PRIOR TO THIS STEP TO AVOID ERRONEOUS SPI DATA TO THE PICOAMP WHILE MEMS Driver IS ENABLED.
3. Remove power as needed, unplug cables or disable inputs, etc.
APPENDIX B: SPECIFIC INSTRUCTIONS FOR MEMS DRIVER – ANALOG INPUT
Bringing Up the Driver

Note: This sequence should be performed and verified the correct voltages are being output before connecting to an actual MEMS Device.

1. Power the Driver board by providing VDD (Pin 3) and GND (Pins 4) to J1.
2. Set the FCLK frequency to control the filter cut-off (Page 10) per recommended settings for the MEMS mirror connected to the PicoAmp.
3. Prior to enabling the MEMS driver, send mirror origin voltage to analog inputs X and Y.
4. Enable the MEMS Driver outputs by sending a TTL High (3V to 5V) through Pin 5 on J1.
   WARNING: BEFORE ENABLING THE MEMS DRIVER, ENSURE THAT THE VOLTAGE OUTPUT ON ANY CHANNEL WILL NOT EXCEED MAX VOLTAGE OF MEMS DEVICE PER THE DEVICE DATASHEET.
5. Now all MEMS Driver outputs X+, X-, Y-, Y+ should be at Vbias defined in the device datasheet. MEMS mirror may move slightly to a new, ‘biased origin.’ This is the MEMS mirror’s zero position or origin.
6. BDQ PicoAmp is now ready to drive the MEMS mirror to new positions. Although signals are filtered, user should avoid discontinuous waveforms with large, abrupt steps or impulses.
7. When ready to plug in the MEMS device: MEMS mirrors should not be connected or disconnected when MEMS Driver Outputs are enabled. Therefore, disable the MEMS Driver (Pin 5 to GND), connect the MEMS device, and re-enable the MEMS Driver.

WARNING: SEE FOLLOWING SLIDES FOR SAFE RANGE OF INPUT VOLTAGES WHEN USING MIRRORCLE MEMS MIRRORS
Analog Input Definitions

- **BDQ PicoAmp: XIN**
  - Input range: -10V to +10V
    - Two X-axis outputs have Vbias and Vdifference(X) between them
  - Origin voltage (no tip/tilt requested): 0V
    - Two X-axis outputs of the driver remain at Vbias

- **BDQ PicoAmp: YIN**
  - Input range: -10V to +10V
    - Two Y-axis outputs have Vbias and Vdifference(Y) between them
  - Origin voltage (no tip/tilt requested): 0V
    - Two Y-axis outputs of the driver remain at Vbias
Analog Output Range Types

- Different MirrorcleTech MEMS Mirrors products may have different required or recommended driving voltage ranges to achieve best performance.

- The most typical driving range or methodology is “Boost 160” or B160 which has following specs:
  - $V_{bias} = 80V$, $V_{difference} = -160V$ to $160V$

- The next category is “Turbo 180” or T180 with specs:
  - $V_{bias} = 90V$, $V_{difference} = -180V$ to $180V$

- The next category is “eXtreme 200” or X200 with specs:
  - $V_{bias} = 100V$, $V_{difference} = -200V$ to $200V$
Output Definition

\[ HV_A = \left(\frac{XIN}{8}\right) \times HVGain + Vbias \]

\[ HV_B = V_{maxMEMSDriver} - HV_A \]

\[ HV_C = \left(\frac{YIN}{8}\right) \times HVGain + Vbias \]

\[ HV_D = V_{maxMEMSDriver} - HV_C \]

<table>
<thead>
<tr>
<th>Name</th>
<th>$V_{maxMEMSDriver}$</th>
<th>$V_{bias}$</th>
<th>$V_{difference \ (Min, \ Max)}$</th>
<th>*HVGain</th>
</tr>
</thead>
<tbody>
<tr>
<td>B160</td>
<td>160V</td>
<td>80V</td>
<td>-160V, 160V</td>
<td>64</td>
</tr>
<tr>
<td>T180</td>
<td>180V</td>
<td>90V</td>
<td>-180V, 180V</td>
<td>72</td>
</tr>
<tr>
<td>X200</td>
<td>200V</td>
<td>100V</td>
<td>-200V, 200V</td>
<td>80</td>
</tr>
</tbody>
</table>

*MEMS Driver circuit Gain tolerance of +/- 1.5%
Applying Desired Input Voltages

- Each MEMS mirror includes a characterization report (datasheet) in pdf and raw data form.
- Static Response characterization provides a reference for dependence of mech. angle on V\text{difference} for each axis. From these V\text{difference} values, \(XIN\) and \(YIN\) are simply calculated:
  - E.g. angle of the mirror needs to be \(+4.5^\circ\) on both axes. From the graph we determine V\text{differences} of ~135V.
  - \(XIN = V\text{difference}(X) \times 4 / HVGain\)
  - \(YIN = V\text{difference}(Y) \times 4 / HVGain\)

Example of Static Response graph from a MEMS mirror datasheet:

Safe range of V\text{difference} for this example MEMS mirror. Exceeding these limits may damage the MEMS mirror.
Shutting Down the Driver

1. Return mirror back to origin by setting the appropriate origin voltages to analog inputs X and Y.

2. Disable the MEMS Driver by sending a Digital Low to Pin 5 on J1.
   
   WARNING: DO NOT UNPLUG OR DISABLE ANALOG INPUTS PRIOR TO THIS STEP TO AVOID APPLYING ERRONEOUS VOLTAGES TO ACTIVE MEMS DRIVER ANALOG INPUTS.

3. Remove power as needed, unplug cables or disable inputs, etc.