



UNCLASSIFIED

G-FET Fluidic Automation Development - Final Report

06/30/2025

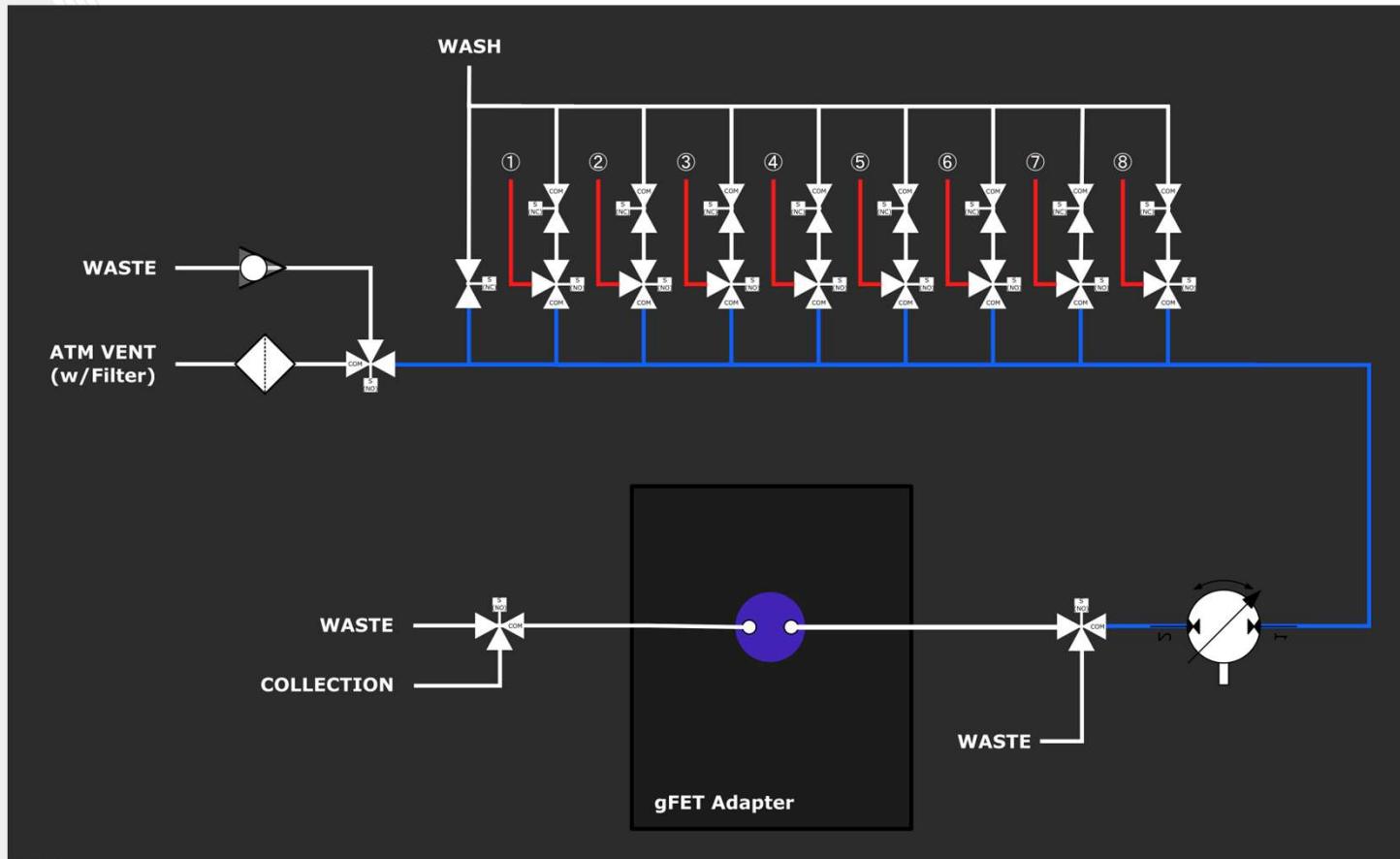
Michael Cato
Research Engineer
Georgia Tech Research Institute (GTRI)
Electro-Optical Systems Laboratory (EOSL)
michael.cato@gtri.gatech.edu | 404-407-7225

Student Intern Support
David Reynolds (GT/GTRI)
Ian Boraks (GT/GTRI)

UNCLASSIFIED

UNCLASSIFIED

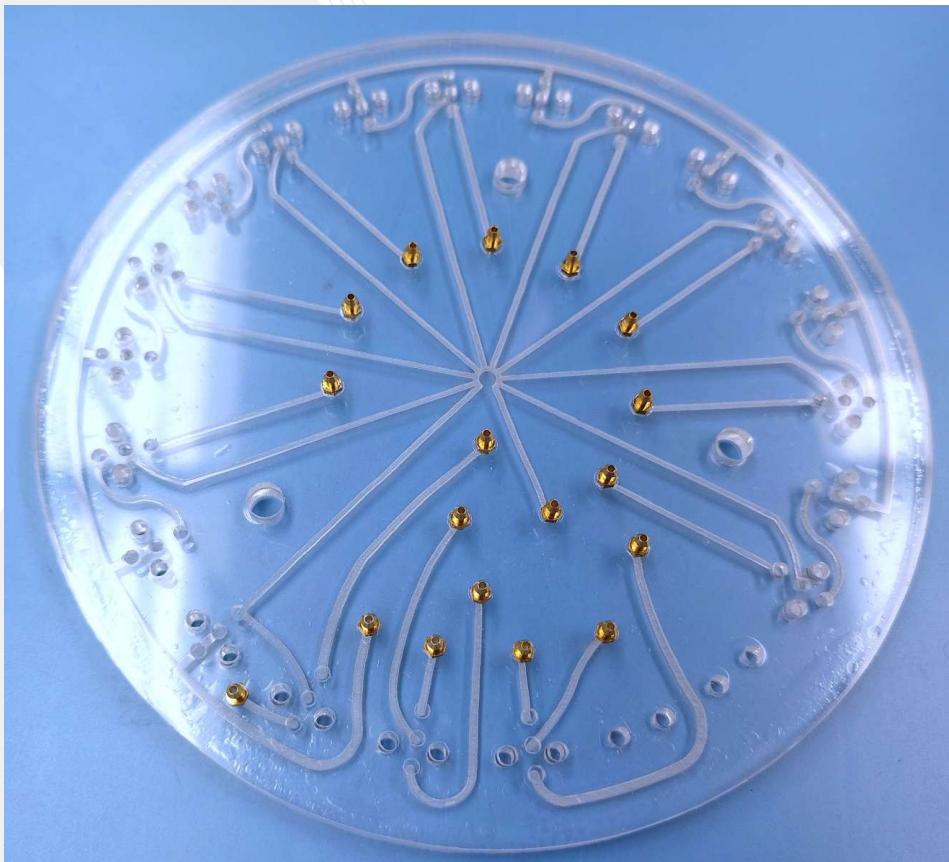
Fluidic Manifold R2 – Fluidic Diagram



UNCLASSIFIED

UNCLASSIFIED

Fluidic Manifold R2



- **Revision Notes**

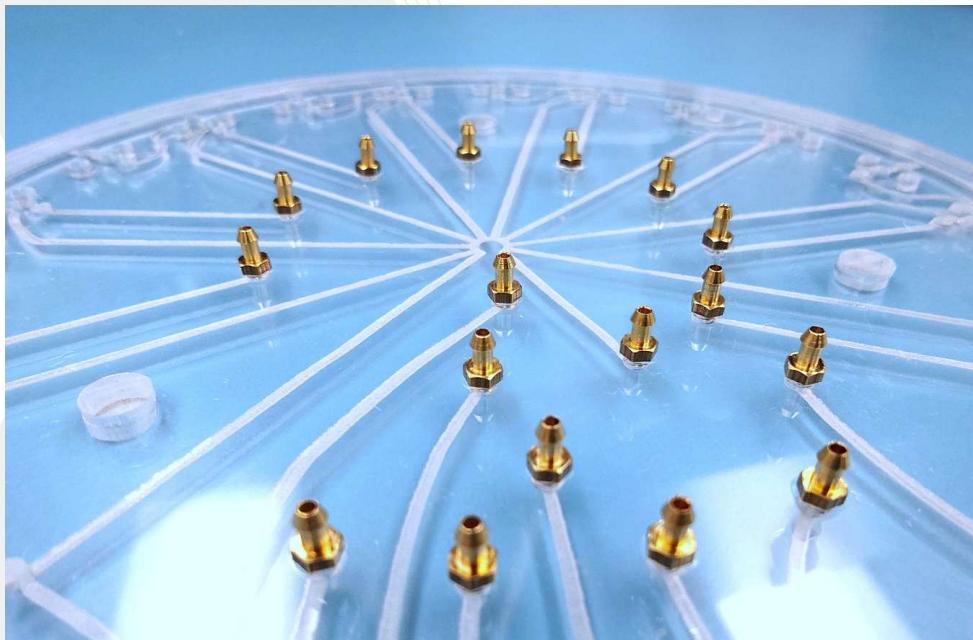
- Increased valve bolt holes by 0.255mm diameter
- Split waste lines into 2 ports
- Rerouted and moved port connector locations
- Rerouted reagent input lines, centered ports between common channel lines for better bonding and clearance tolerance
- Reduced barb connector holes by 0.1mm diameter
- Added 0.9mm diameter for 3x mounting bolt holes
- Updated fluidic schematics to reflect changes
 - Note that the reverse GFET wash function and valves were removed, and should also be disabled in the firmware
 - A check valve was added to the schematic for the air vent valve
 - A filter was added to the schematic for the air vent
- Updated port label diagram to reflect changes
- Updated fluidic routing diagram to reflect changes

UNCLASSIFIED

UNCLASSIFIED

Fluidic Manifold R2

- Fab Notes

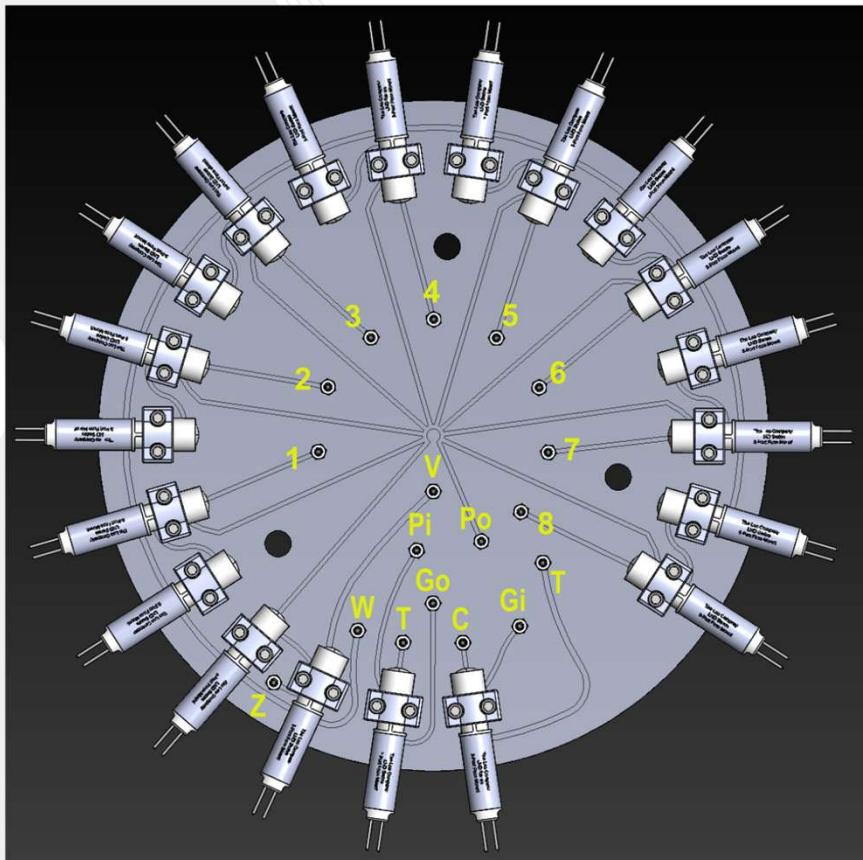


- Wafer Etching OK
- Wafer Bonding OK
- Wafer Alignment Tolerance OK
- Barb Connector Installation OK
- Barb Connector Sealing OK
- Functional Lamination Defects OK
- Fluidic Continuity OK
- Fluidic Pressure Tests OK
- Other Notes
 - Cosmetic defects observed on outer surfaces due to trapped pressurized gasses during bonding

UNCLASSIFIED

UNCLASSIFIED

Fluidic Manifold R2 - Port Labels

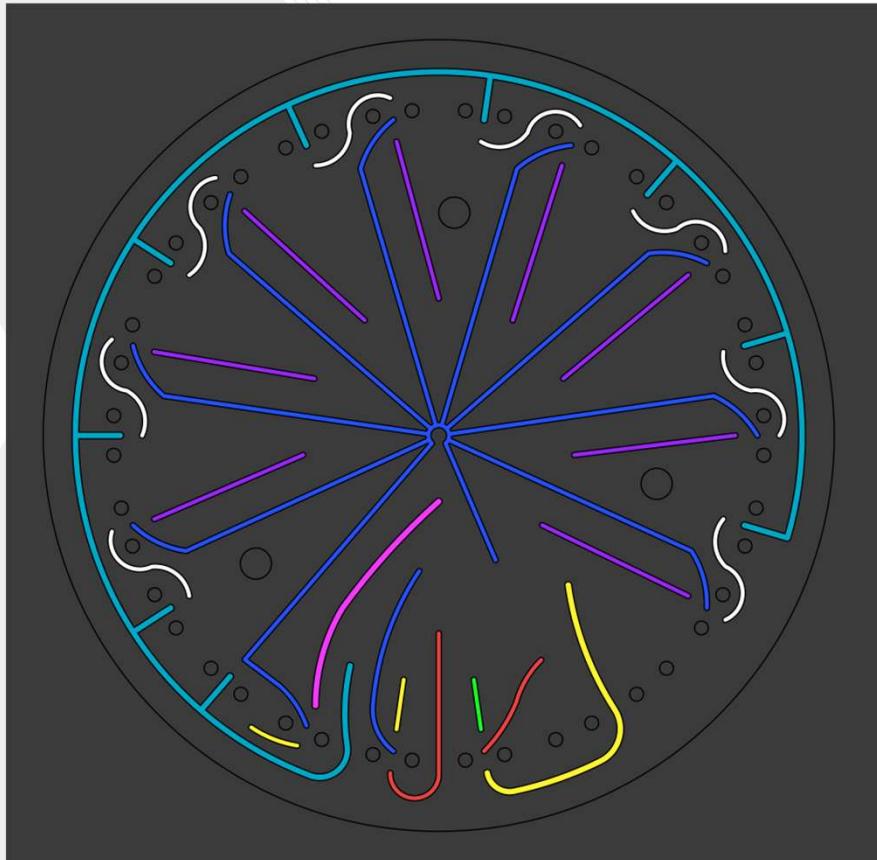


1-8	Reagent Inputs
V	Air Vent (Filter) Input
Po	Out to Pump
Pi	In from Pump
Go	Out to GFET Adapter
Gi	In from GFET Adapter
W	Wash Input
C	Collection Output
T	Waste Lines
Z	Waste (w/Check valve)

UNCLASSIFIED

UNCLASSIFIED

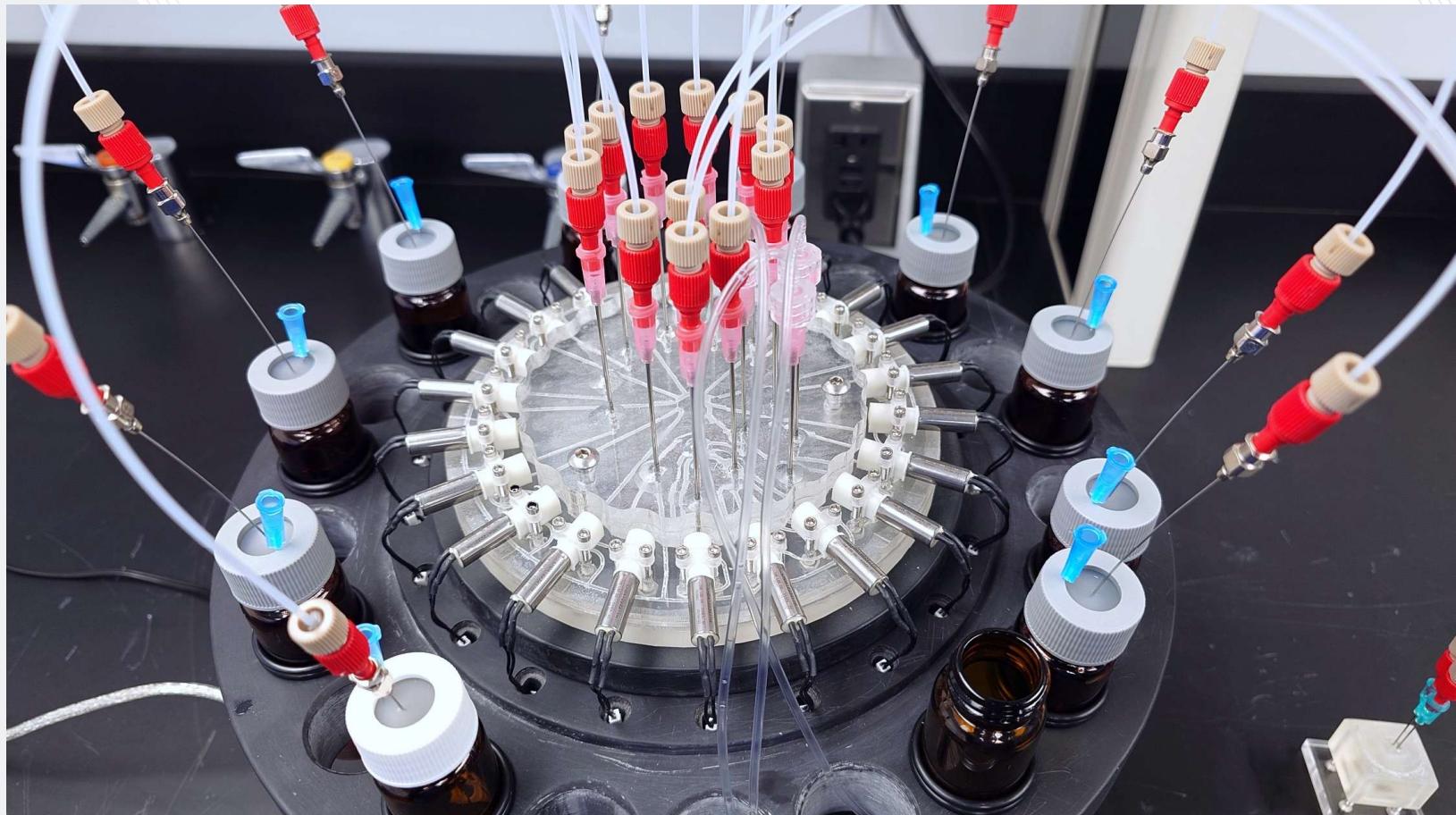
Fluidic Manifold R2 - Routing Diagram



- Common, Pump Out, Pump In
- Wash
- Reagent Inputs
- Wash Gate
- Waste
- GFET Out, GFET In
- Air Vent
- Collection

UNCLASSIFIED

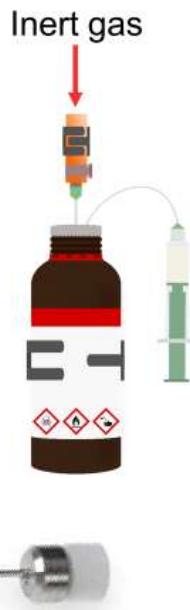
System Assembly (R0)



UNCLASSIFIED

UNCLASSIFIED

Reservoir / Reagent Storage

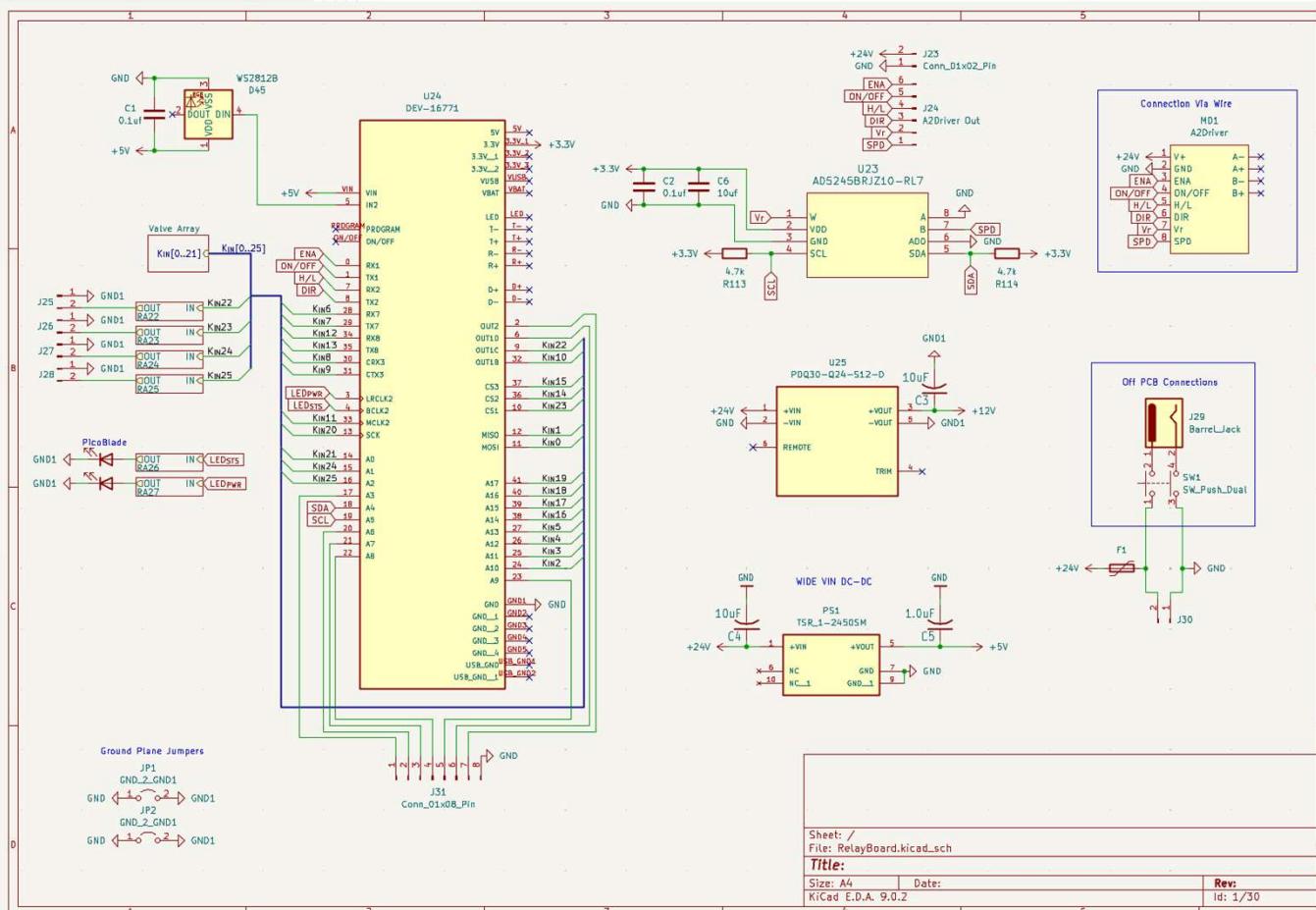


- Vial Holder / Rack
- 40-60mL Reservoir Vials
 - Vial Cap with Septa
 - Must apply inert gas or vent to ATM
- Solvent Needles
 - Extract reagent while pumping
- Vent Needles
 - Supply inert gas or vent to ATM with or without syringe filters
- Chemical Compatible PEEK Tubing
- HPLC & Luer Fittings

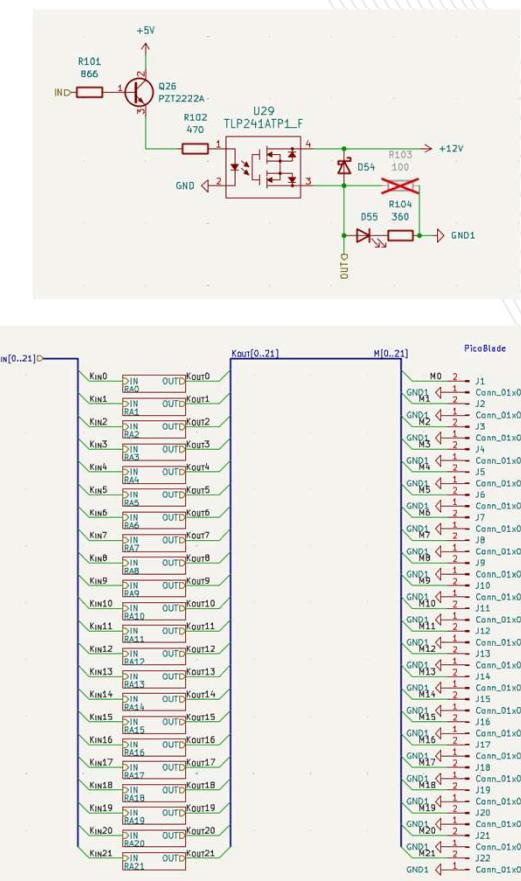
UNCLASSIFIED

UNCLASSIFIED

Electrical Schematic



UNCLASSIFIED



UNCLASSIFIED

Teensy 4.1 Micro-Controller and Pinout

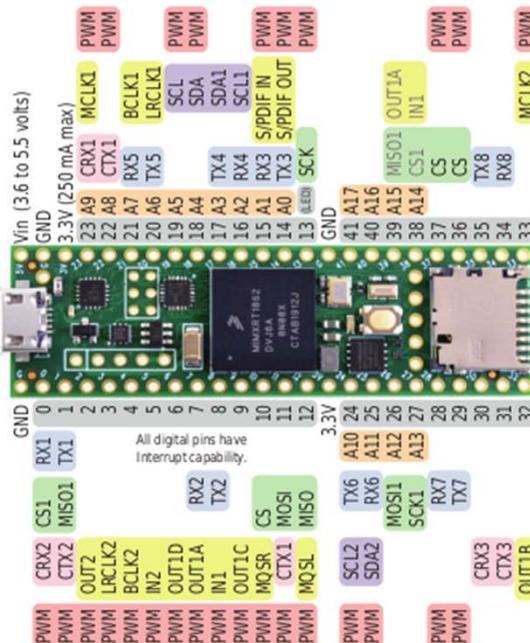
- PJRC Teensy 4.1
 - <https://www.pjrc.com/store/teensy41.html>
 - Requires Arduino w/Teensyduino package installed for programming and serial communication
 - <https://www.arduino.cc/en/software/>
 - <https://www.pjrc.com/teensy/teensyduino.html>
 - External 24VDC power must be plugged into the system and the power switch enabled before firmware programming or initiating serial communication
 - Firmware programming can be performed using the USB B Port on the front panel of the system

Welcome to Teensy® 4.1

32 Bit Arduino-Compatible Microcontroller

To begin using Teensy, please visit the website & click [Getting Started](#).

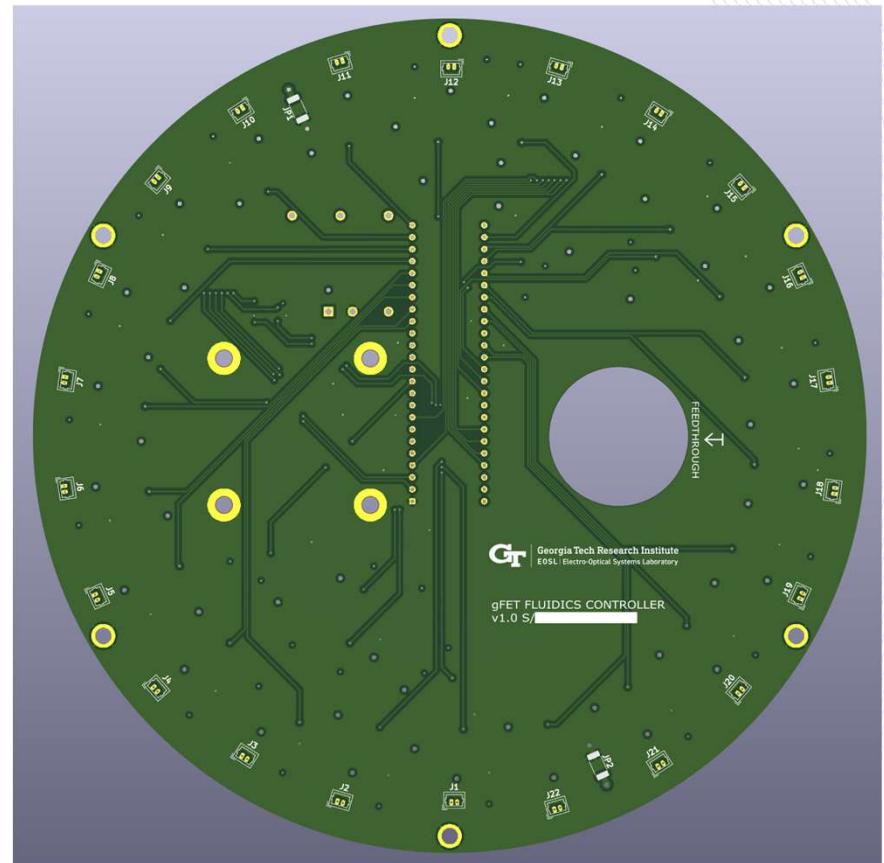
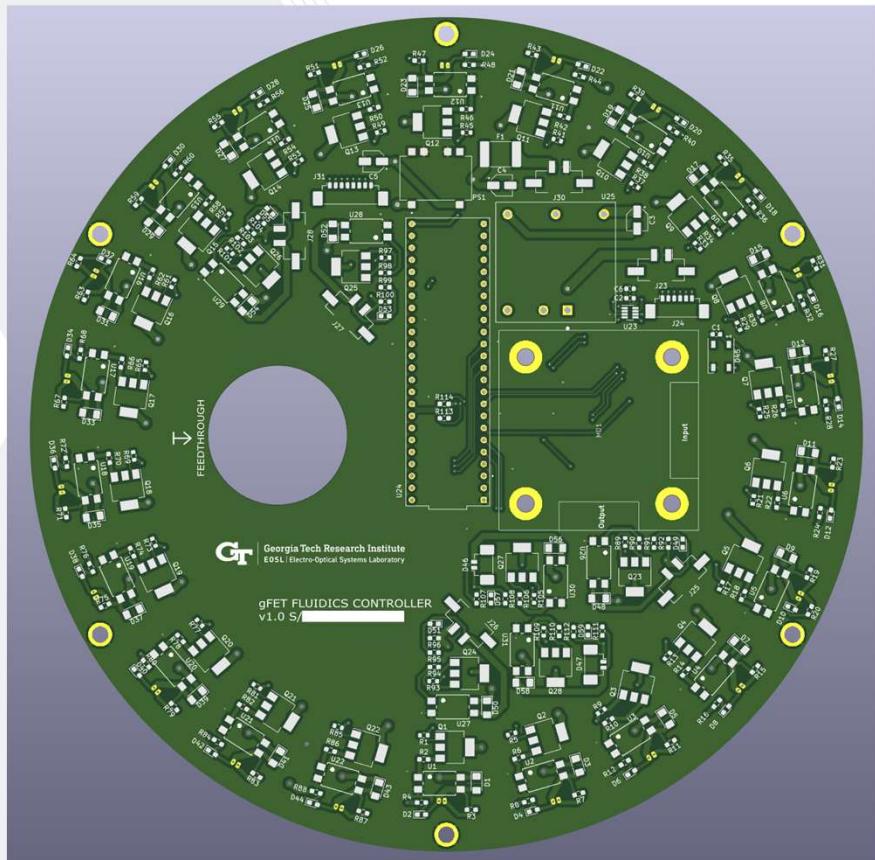
www.pjrc.com/teensy



UNCLASSIFIED

UNCLASSIFIED

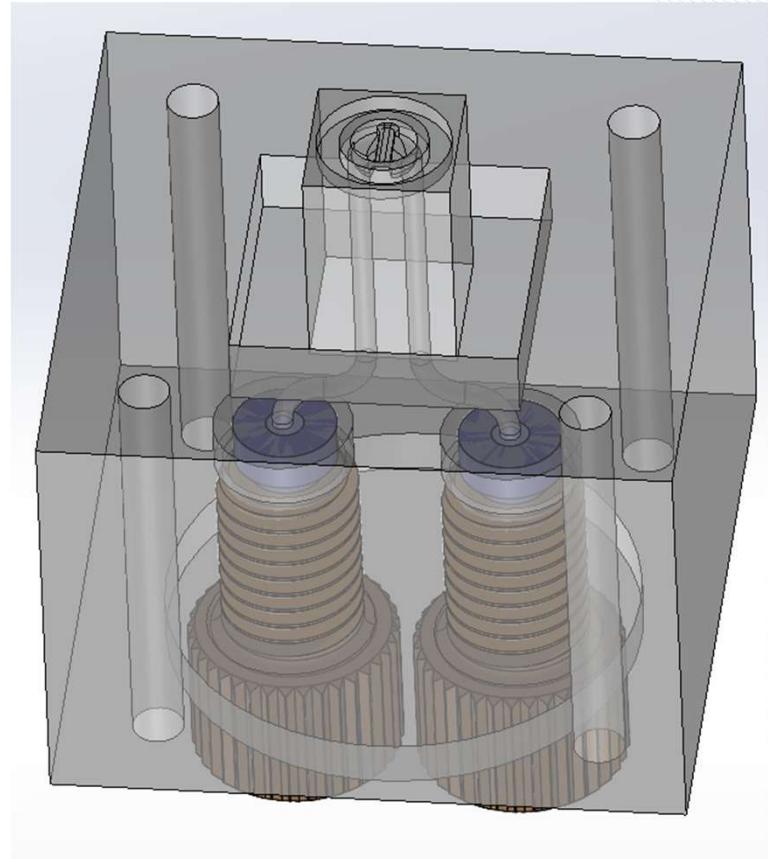
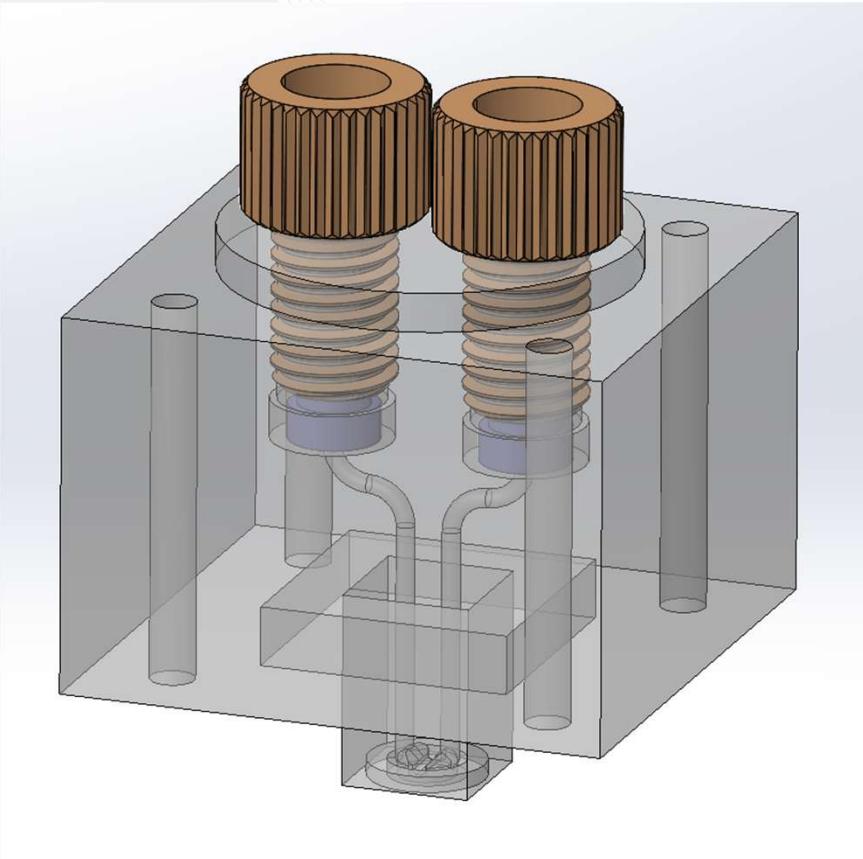
Printed Circuit Board



UNCLASSIFIED

UNCLASSIFIED

G-FET Fluidic Reservoir Adapter

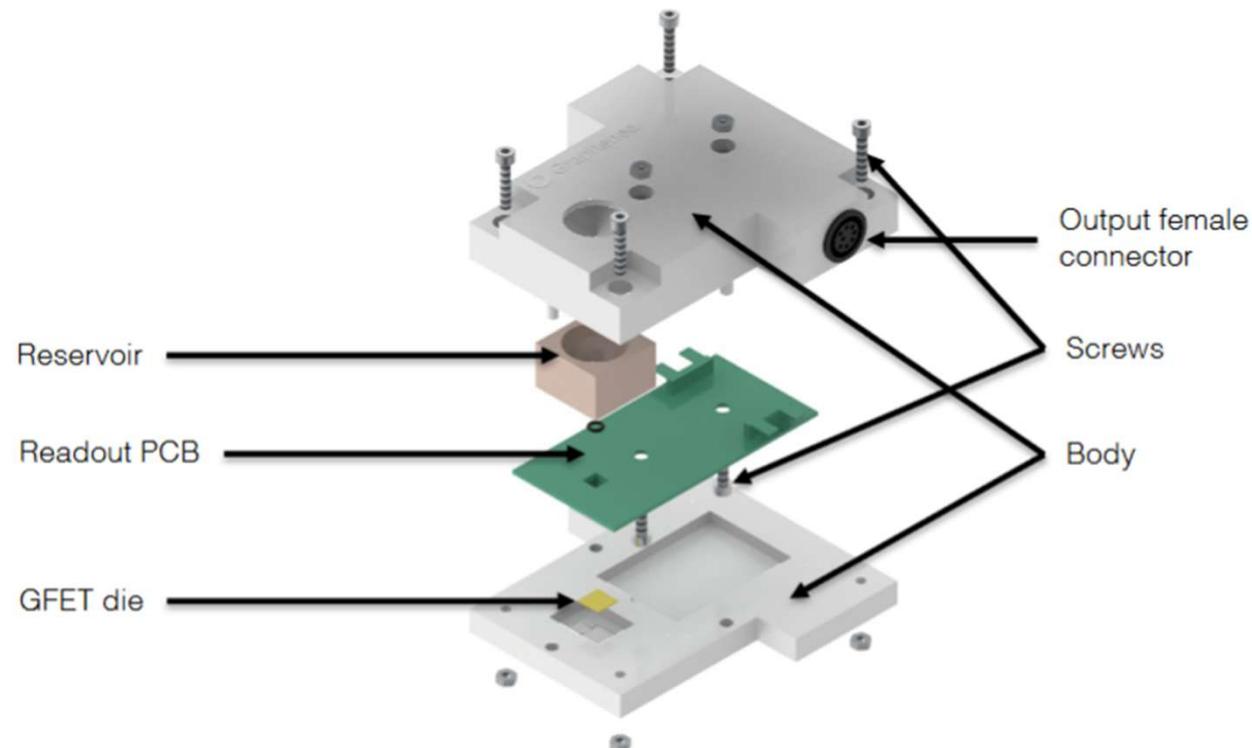


UNCLASSIFIED

UNCLASSIFIED

G-FET Adapter Interface (COTS)

General Schematic



UNCLASSIFIED

UNCLASSIFIED

Accessories & Replacement Parts

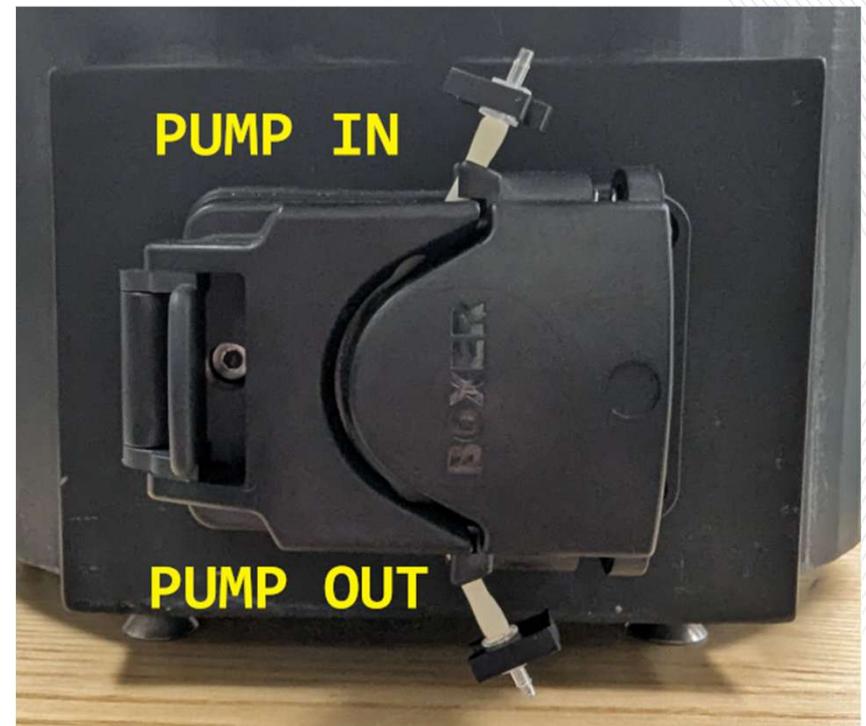
P/N	Description	Manufacturer	System Usage
XP-235	Flat Bottom Fitting PEEK with Compression Ferule 1/16in	Idex Health and Science	Fluidic Connectors
P-675-01	Luer Adapter Male Luer x 1/4-28 Female Tefzel	Idex Health and Science	Fluidic Connectors
8349T11	1/32" ID, 3/32" OD, Soft ND-100-65 Tygon PVC Tubing for Chemicals	McMaster-Carr	Fluidic Tubing
1531BXL	Tubing PEEK Blue 1/16 x .010 x 100ft	Idex Health and Science	Fluidic Tubing
1902L	Tubing HPFA+ 1/16 x .010 x 50ft (alternate tubing option)	Idex Health and Science	Fluidic Tubing
51525K291	Plastic Luer Lock Tube Coupling for Air & Water Polypropylene Socket, Barbed, 1/16" Tube ID, White, 40 PSI Maximum	McMaster-Carr	Fluidic Connectors
1605N141	Syringe filter 1in diameter, luer lock, 0.22um PTFE, PP housing	McMaster-Carr	Air Purge Vent Filter
SLFGR04NL	Millex™ hydrophobic PTFE syringe filter pore size 0.2 µm, diam. 4 mm, non-sterile	Millipore	Septa Vent Filter
)305122	BD General Use and PrecisionGlide Hypodermic Needles 25 G, 0.62 in. length, 0.02 in. diameter, Regular	BD	Vial Septa Vent Needles
S386150	Stainless Steel Solvent Syringe Needles 150mm length, 0.6mm diameter	Synthware	Vial Reagent Pickup Needles
48781	60mL Dionex ASE Amber Collection Vials Glass	Thermo Scientific	Reagent Vials
48780	40mL Dionex ASE Amber Collection Vials Glass	Thermo Scientific	Reagent Vials
9600.76	9QX Peristaltic Pump, 6 rollers, no driver, no encoder	Boxer GmbH	Pump
3824N119	Detachable Cord AC to DC Adapter 24VDC, 1.5A Barrel Output, 120/240VAC IEC C14 Input (requires old connector)	McMaster-Carr	Power Adapter
LHDX0307140A	Valve Mounting Clip	The Lee Company	Valve Mounting Hardware
9000.761	Innovaprene 0.5 dia. x 1.0mm w/PP connectors	Boxer GmbH	Pump Tubing
9000.762	Innovaprene 1.0 dia. x 1.0mm w/PP connectors	Boxer GmbH	Pump Tubing
1174N115	Buna-N O-rings 4mm ID 1mm Width 50A Durometer	McMaster-Carr	Reservoir Adapter
500500KV-001S000	Check Valve In-line 1/16 Barb Tube Fittings, low PSI Rated	SmartProducts USA	Air Purge Vent Check valve



UNCLASSIFIED

UNCLASSIFIED

System Panel Labels

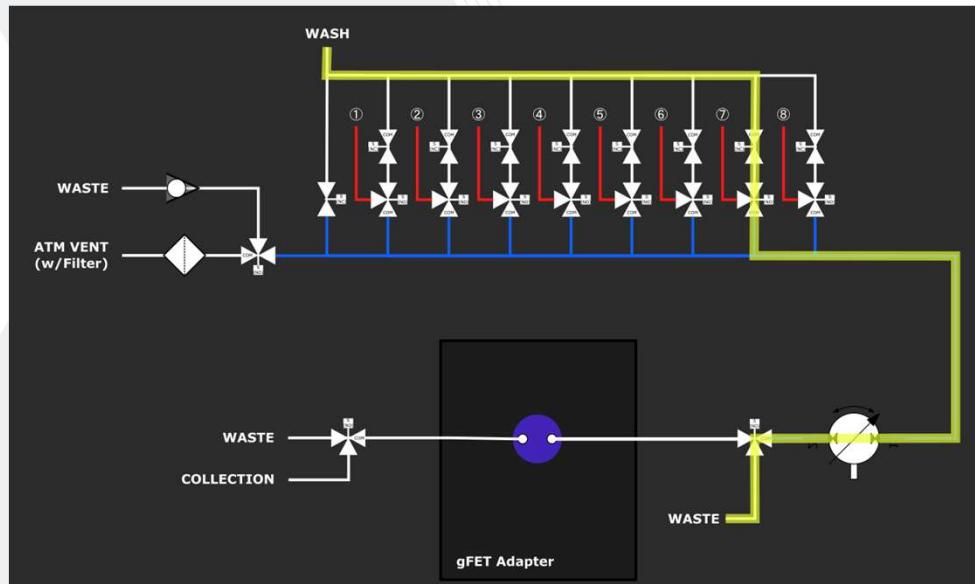


UNCLASSIFIED

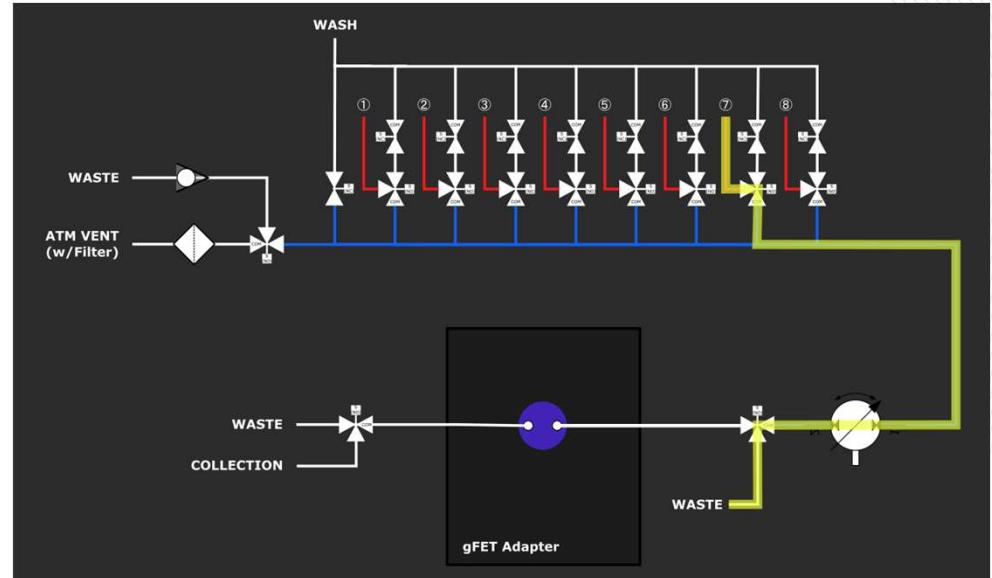
UNCLASSIFIED

Serial Command Examples

PRIME CHEM_WASH 7 -T ## -R ##



PRIME -C 7 -T ## -R ##

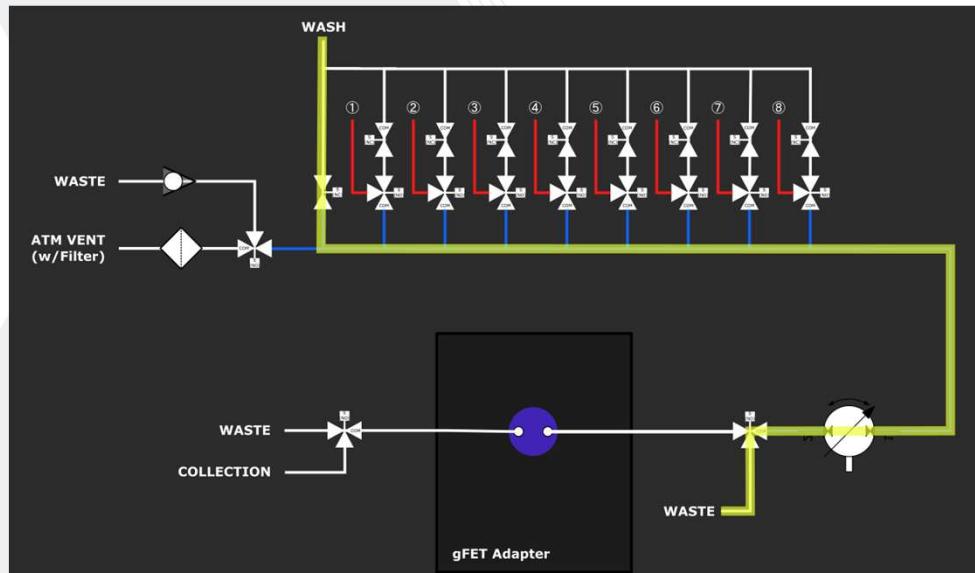


UNCLASSIFIED

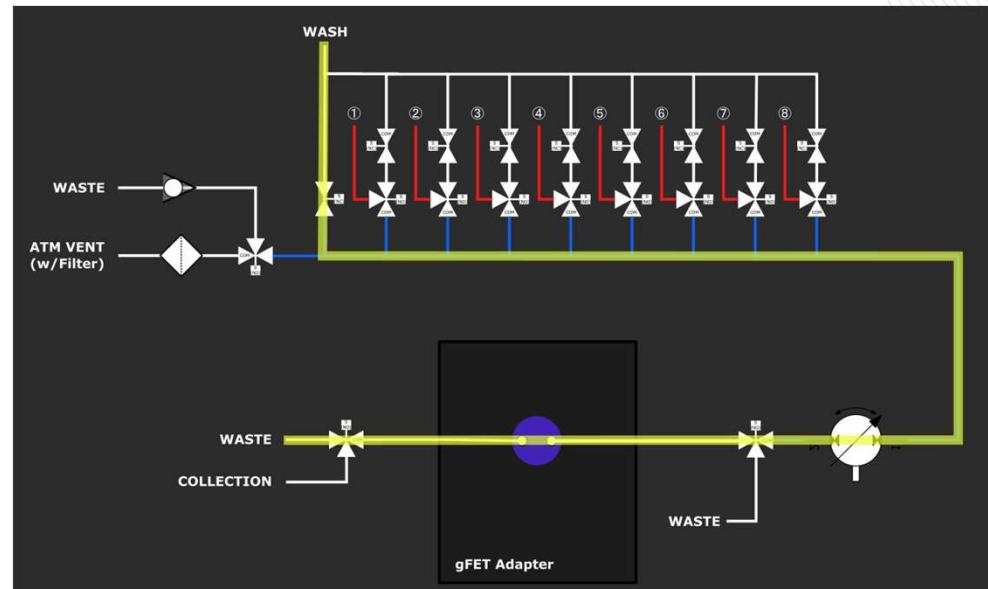
UNCLASSIFIED

Serial Command Examples

WASH COMMON 0 –T ## -R ##



WASH COLLECT 0 –T ## -R ##

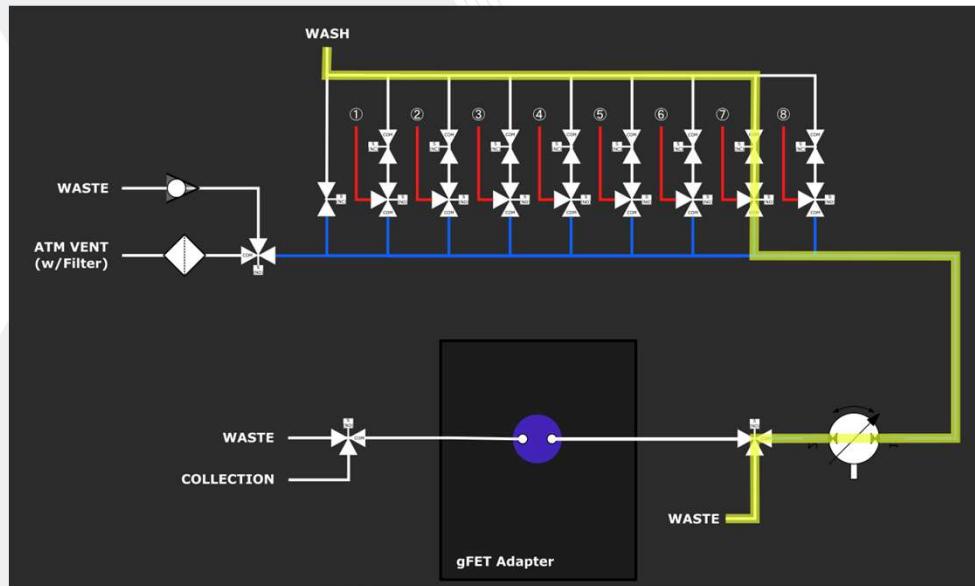


UNCLASSIFIED

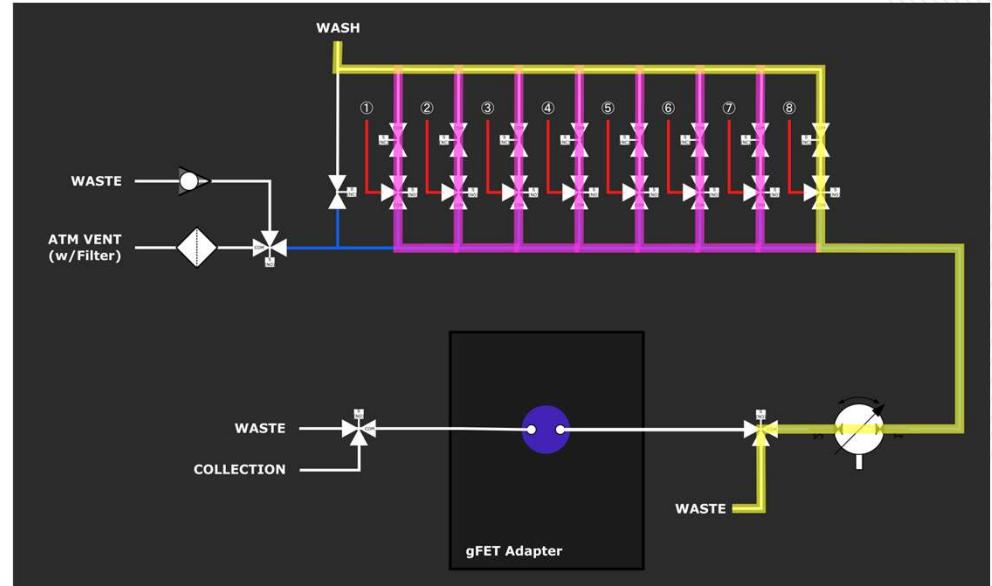
UNCLASSIFIED

Serial Command Examples

WASH -C 7 -T ## -R ##



WASH CHEM_WASH 0 -T ## -R ##

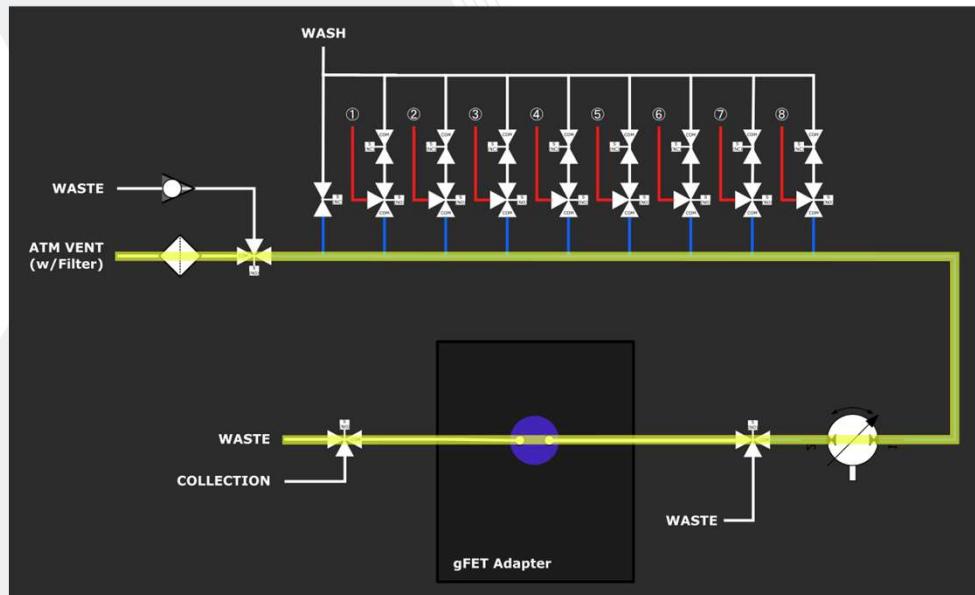


UNCLASSIFIED

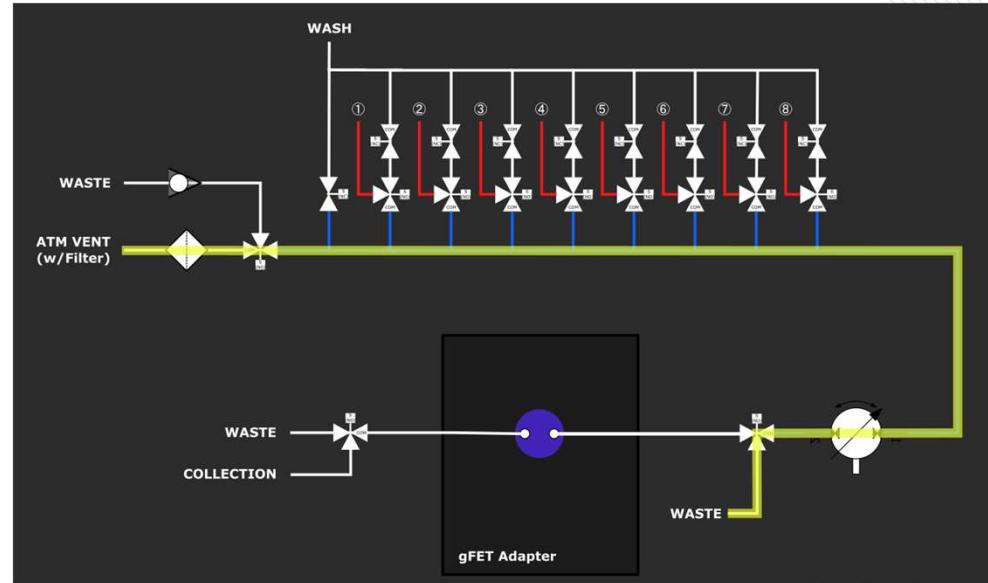
UNCLASSIFIED

Serial Command Examples

PURGE ALL 0 –T ## -R ##



PURGE COMMON 0 –T ## -R ##

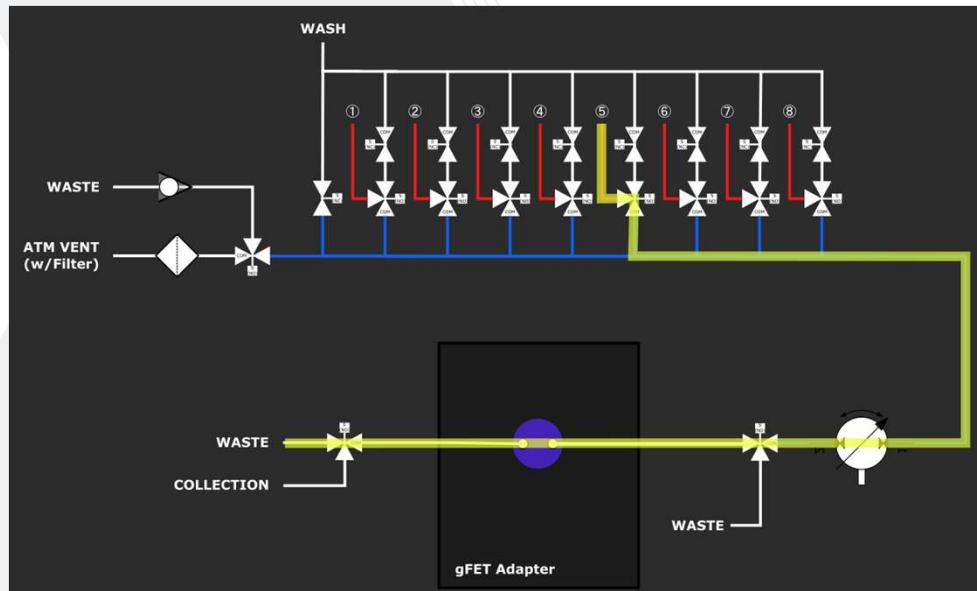


UNCLASSIFIED

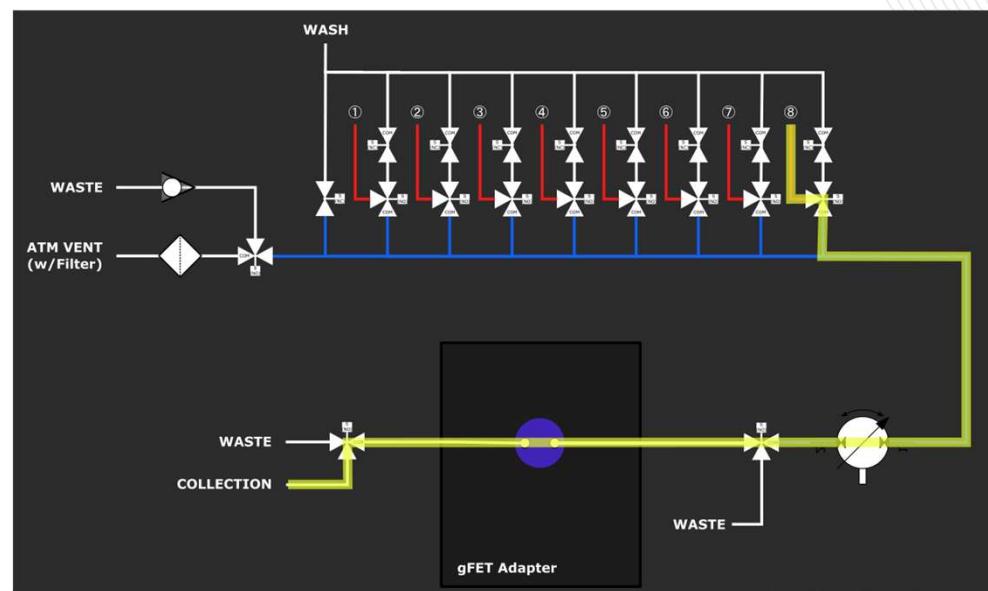
UNCLASSIFIED

Serial Command Examples

PUMP –C 5 –T ## -R ##



COLLECT –C 8 –T ## -R ##



UNCLASSIFIED

FAQs

- **Micro-bubbles appear in manifold channel or tubing**
 - Check for leaks at fluidic connectors, insure that the luer lock fittings are tight on the low pressure side of the manifold
- **No fluid flow while pump is enabled**
 - Check for blockages
 - Check that peristaltic tubing is seated properly and engaged with the roller
 - Confirm that vent needles are installed in vial septa caps
 - Check for obstructions to flow including septa vent needles and septa vent needle filters if installed
 - Check for fluid level at solvent needles in vials
 - Check for clog at solvent needles in vials
 - Check valve operation
 - Check for pump suction
 - Check for pump pressure
- **Check that peristaltic tubing is seated properly and engaged fully with the roller**
 - Visually inspect, and reseat peristaltic tubing if needed, check that black plastic clips are installed against pump housing to keep tubing snug on rollers but not pinched
 - To test operation, disconnect the tubing from the manifold for both sides of the pump
 - Insert the manifold "pump output" (pump input side) tubing into a vial/beaker of DI water insert the manifold "pump input" (pump output side) tubing into an empty vial/beaker
 - Operate pump, check for output flow into empty beaker
 - If output is weak, replace the peristaltic tubing with new tubing or readjust the seat
 - If operation is normal, reconnect the tubing to manifold and test for suction and pressure

FAQs

- **Check for pump suction (with the pump output side disconnected)**
 - Disconnect “pump input” tubing from the manifold (the output side of the pump)
 - Insert tubing into an empty vial/beaker
 - Try running the wash collect command
 - If Normal Flow is observed
 - Suction side of manifold is OK
 - If Normal Flow is not observed
 - Check for blockages in suction side of manifold, valves, and solvent needles
 - Check that vial septa vent needles are installed
 - Check that luer lock connections are tight and not leaking
 - Check for damaged tubing
 - Check that valves are seated properly
- **Check for pump pressure (with pump input side disconnected)**
 - Disconnect “pump output” tubing from the manifold (the input side of the pump)
 - Insert tubing into a vial/beaker filled with DI water
 - Try running the wash collect command
 - If Normal Flow is observed
 - Pressurized side of manifold is OK
 - If Normal Flow is NOT observed
 - Check for blockages in pressurized side of manifold, valves, and the GFET Adapter

FAQs

- **Pulsating fluid in channels and tubes but no flow**

- Check that peristaltic tubing is seated properly, and engaged fully with the roller
- Check if peristaltic pump is fully rotating or stalled
- Check that appropriate valves are opening
- Check for clogs or obstructions
- Check for leaks in fluidic connectors

- **Reduced pump suction or flow rate issue**

- If ruled out other suction related issues
 - Try increasing flow rate in firmware commands, but make sure to limit to prevent stalling and do not go higher than the max rate of pump
 - If pump roller slippage is an issue due to wear, or more suction is required, replace tubing or switch to peristaltic tube with larger diameter ID and OD
 - Current tubing is Boxer p/n 9000.761 (Innovaprene 0.5 dia. x 1.0mm w/PP connectors)
 - Next Size up is Boxer p/n 9000.762 (Innovaprene 1.0 dia. x 1.0mm w/PP connectors)
 - Will increase flow rate (4x) and fit more tightly against pump rollers, but requires 4x the fluidic volume
 - Recommend dropping flow rate on the serial command to account for higher flow rate, slowly increment higher as needed
 - <https://www.boxerpumps.com/products-shop/accessories/9qx-9qq-9k/>
 - Increasing solvent needle inner diameter (ID), vial septa air vent needle ID, air vent needle filter, PEEK/PFA tubing ID, reduce other constrictions, and/or test faster pump flow rates as needed

- **Low Air Vent Flow Rate on vial septa needle filters and purge air vent valve input filter**

- Use filters with larger pores and/or high surface area to increase flow rate
- Replace old or dirty vent filters, especially if not operating in a HEPA/ULPA filtered clean room or laminar flow hood

UNCLASSIFIED

Files

REPORT (.pdf)

→ \GFET_FINAL\DOCS\GFET_FINAL_REPORT.pdf

COMMAND RUNNER SCRIPT (.py)

→ \GFET_FINAL\CMD_RUNNER\Command Runner.7z

FIRMWARE (.c, .ino)

→ \GFET_FINAL\FIRMWARE\GFET_FIRMWARE.7z

API DOCUMENTATION (.pdf)

→ \GFET_FINAL\DOCS\API Documentation.doc

PCB SCHEMATICS (.pdf)

→ \GFET_FINAL\PCB\GFET_PCB_Schematics.pdf

PCB BOM (.xlsx)

→ \GFET_FINAL\PCB\GFET_PCB_BOM.xlsx

PCB GERBERS (.gbr, .drl, .png)

→ \GFET_FINAL\PCB\GFET_PCB_Gerbers.zip

CAD MODELS (.stl, .dxf)

→ \GFET_FINAL\CAD\

UNCLASSIFIED