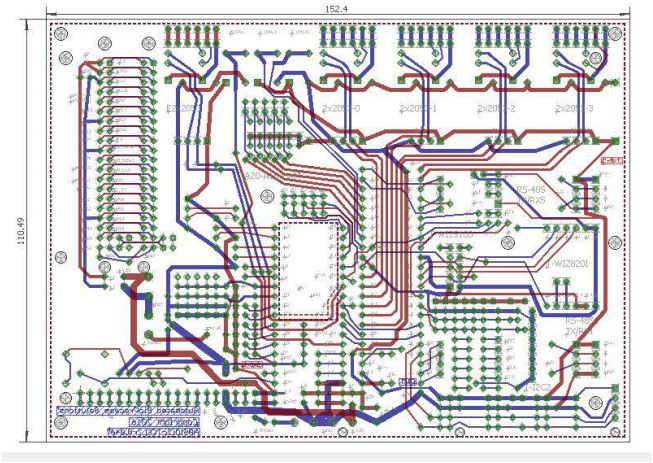

Figure 1. TELEZ trio IIoT board

Automated
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Simply smaller, with the power of connectivity.

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Automated BioProcess Solutions IoT Portfolio

Conventional control systems, including PLC/ DCS architectures, usually have extended deployment life-cycles and new technologies need to be incorporated into existing systems. Protocol converters for existing systems, and design modifications to process systems for modernization are to be expected. These activities benefit from modular and object oriented concepts for component replacement and upgrade. Modular concepts are especially applicable to small systems that can integrate into existing older technology bases. Innovative companies need cost effective development systems, and they can modify, without large license fees to the automation companies. Closed door software inhibits that migration. TELEZ life-cycle agility is introduced via off the shelf hardware and open source software environments as a means to enable a cost effective development platform that expresses innovation which is encapsulated as a thing (IoT) that readily integrates with existing industrial or commercial controls to offer a boost of new technology features to those systems or completely new ones..

The following Unit Operation IoT designs are available; Use these, or define your own application and apply these technical concepts as needed for your IoT device. The controller code is either cross platform usable or adapted to your desired flavor of Control Processor. Processor sets are selected on communication needs and application scope for a personalized IoT device

The schematic above, is the TELEZ modular microprocessor carrier. This environment provides plug-gable sockets for several common processor families that share a data-bus and can pass information among themselves or to external devices. With a trio of processors, conventional process control and sequencing is executed. Tasks are divided among the trio according to necessary resources and communication partners. The base configuration with a solo TEENSY provides a dedicated Real-time processor and hardwired factory floor network access. Cellular Modem/wireless cloud processor is a PARTICLE with SPI link to the TEENSY. Cloud communications node slaved to other processors as it requires secure isolation form the real-time process or file server. The Raspberry PI Linux file server capability enables local development, visualization, and reference document availability. The Linux environment or external laptop programs the processors on the board over USB and secure shell.

Many arrangements are possible to either act as subordinate, peer to peer, or in administration of external slave devices. These processors each use a set of common software for supervisory or direct control of devices. A useful, reusable library of control algorithm building blocks or Control Modules has been developed and can be compiled cross-platform using accepted AVR/ARM.

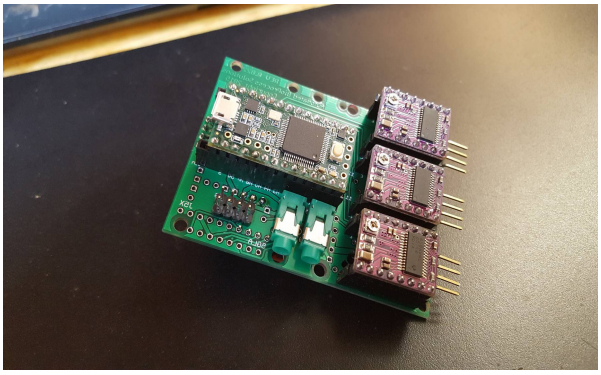

Figure 2. Stepper or pump driver slave T3.2 (ARM) 3 axis with feedback inputs and limit switch I/O.

AN Example slave I2C or RS485

Small control signal I/O (input/output) "shield" type slaves are available for modular or smaller sub-systems associated with typical control systems. These smaller board modules can act as nearby slaves to the TELEZ, or another CPU. Any of these I/O slaves can support wireless, hardwired Ethernet, or serial communications and each has a local processor capable of local control. The smaller boards are available in either ARM or AVR flavors for instrument interface or final control element outputs to mix and match much like a traditional programmable logic controller. Communication with slave devices is via serial I2C or RS485. This device can run standalone as well and drive a display.

Examples of I/O slave configuration are given in the following sections to illustrate something like a device you may need ; Most of these IoT devices are composed of slave combinations. TELEZ master boards are found in TFF, Filler, and Reactor IoT clusters that could also integrate additional slaves.

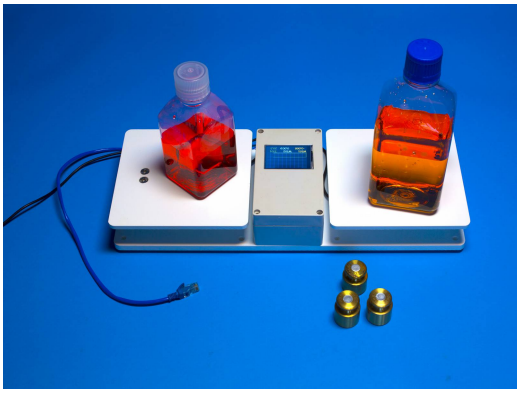

Figure 3. Dual 10Kg scale with touch graphic

Ethernet Weigh Scale Array

- 64 measurement channels per Ethernet connection.
- Various Industrial protocols supported.
- Touchscreen interface/remote interface available.
- Process alarming is supported.
- Optional PI zero with a wireless module is given for size reference.
- This unit can be made from either AMTEL or FREESCALE processor core slaves.
- Typical performance is 14-bit resolution

Process Equipment:

This scale provides a process capable I/O point. The weights or other measurements graphically correlated on an optional display. Expandable to mix and match I/O types for data acquisition or correlation that matches your process measurement needs (e.g. pressure, pH, et.al.). Additionally, this unit can function as a sequencing controller. It supports local slaves for motor and valve actuation.

Communication/IoT:

The unit shown is hard-wired Ethernet, and uses MODBUS TCP to communicate with the client's lab data system. The Ethernet available data structures are readily communicated via a server task onboard. Slave I/O modules can accommodate recipes, data collection and storage. This also useful as an interface to major instrument manufacturers or PLC from legacy/serial devices and in execution of moderate sequential control.

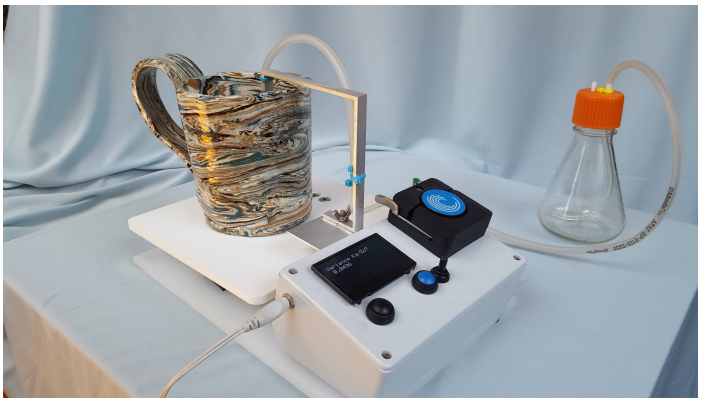

Figure 4. Five to 10000 gm, larger pump/scales possible

Weight Dispensing Pump Controller

- Dosing or blending
- Flow rate control rate
- Feedback control of a process variable.
- Network Server capable. Configurable for tubing size, and control mode.
- Various operator interfaces including touch screen available.

Process Equipment:

This unit is programmed to repetitively deliver an adjustable weight target to a user defined amount and tolerance, or target rate. The unit will calculate speed profiles based on your tubing selections and pumps speed availability. If the parameters you select can't do what you want it lets you know that too. Once reasonable parameters are supplied, the unit calculates a simulated filling time and provides a table of the projected speed and filling time along with the expected accuracy and the required speed profile to achieve the dispense or flow rate. The unit can also calculate tubing characteristics to identify abnormal tubing wear or feed malfunction.

Operational speed profile calculated dynamically, the performance of the unit adapts a dynamic target. The basic system interfaces with many different pump types; this one is a stepper motor drive under direct control.

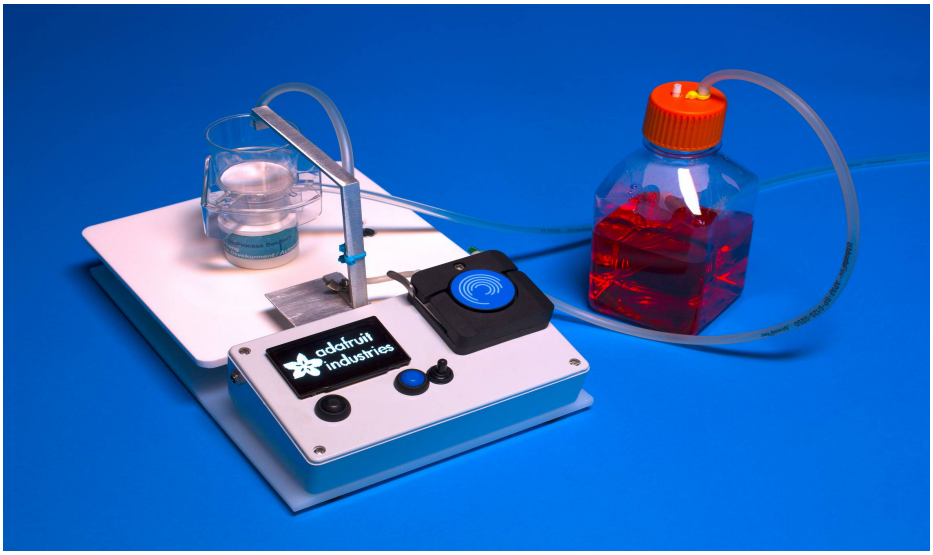

Figure 5. setup for delivery of sample to the vacuum filter by total weight

Communications/IoT:

Optionally configure on boot using the USB port, and then use network registers after boot-up to change parameters online, on-the-fly. Various user interfaces are possible. The one shown is the most economical monochrome graphic display. Units with industrial Ethernet HMI communication can control multiple devices. The filler shown later builds on this concept.

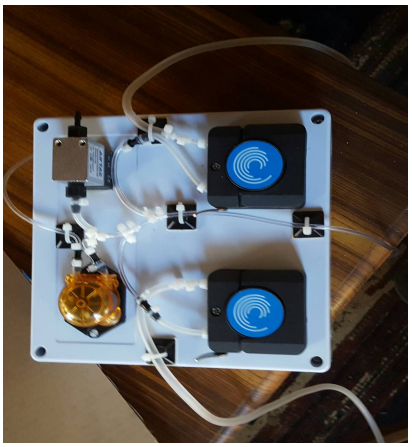

Figure 6. A blind slave sample server

Network Sampler/Mini CIP

Miniature CIP unit with air blow for sample isolation or continuous stream analysis unit.

- Dimensions of 7”x7”x4”.
- Optional UV sterile barriers for sterile disposable operation.
- Optional process status light stack.
- Digital process value for sensor readings.
- Sensors can be analog or serial instruments.
- Industrial Ethernet network Process data collection.
- Cleaning recipes are configurable over the network for adaptation of cleaning cycles.

Process Equipment:

The unit above and the one below have process sequencing flexibility in a small package. This functions as miniature sample prep station with measurement capability and data analysis for remote users. The unit cleans itself for intermittent operation or functions as a small slip-steam sampler with flexible pump and tubing configurations. This unit accommodates auxiliary instruments for data acquisition or slave processor sequencing of a YSI analyzer. The pumps are reversible and the unit has an on-board mini compressor for air blows to enhance cleaning velocities while at the same time minimizing hold-up volume and sample volume.

On-line glucose measurements executed with sample volumes of a few milliliters. Micro tubing pumps and valves will achieve even smaller hold-up volumes (micro-liters). Sample isolation was better than three $\log_{10}$ after recipe development. This unit can coordinate with your industrial CIP skid to perform 100% verification of final cleaning conductivity and purity.

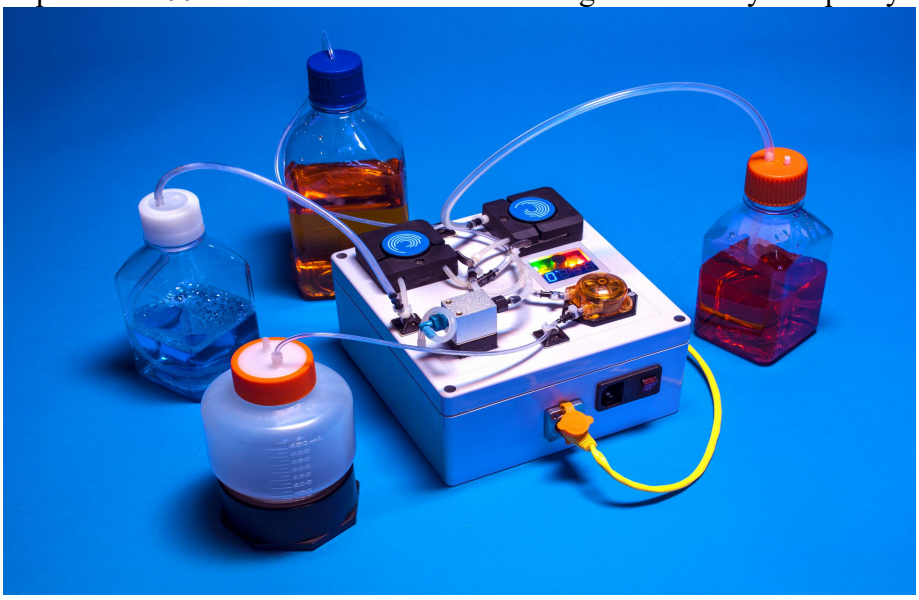

Figure 7. Optional phase state display and local readout of process value and sample ID

Communications/IoT:

The unit performs with the smallest of processors or excels with an ARM M4 processor to add more pumps or data analysis. The unit shown has a communications capability for MODBUS TCP and uses

AVR Amtel MEGA2560 with an Amtel 328P Stepper slave. Operational recipe configuration parameters via Network for cleaning cycle PHASE parameters. This device can interface with an external analyzer via either serial, network, or analog voltage measurements.
With a reasonable ARM processor like a TEENSY 3.2 or 3.6, tracer analysis is performed locally, and local data storage in the event of communication interruption is available. The extra computing capacity enables local, rapid, calculations. When used with an in-line sensor set , these include chromatography performance attributes : dispersion coefficients, or HETP calculations, or peak detection. An inline process measurement arrangement would likely not need pumps but could interface to a PLC as a high speed floating point slave with control capability and coordination.

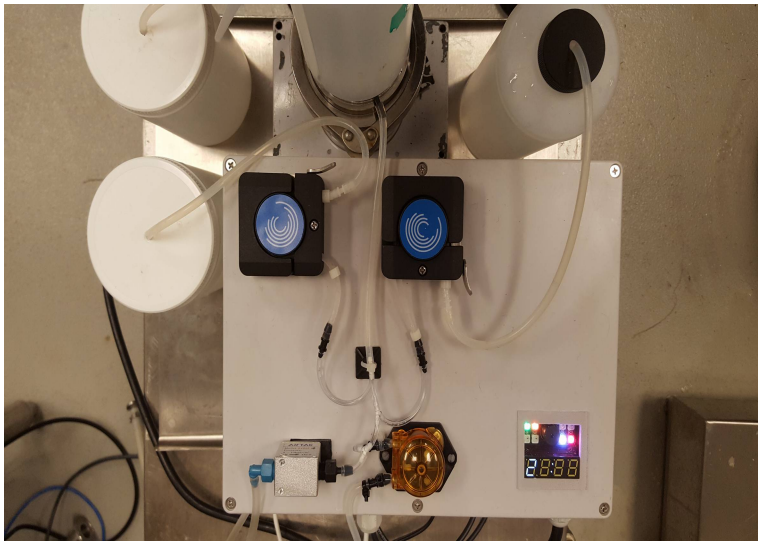

Figure 8. Configuration used for monitoring of a Bio-Reactor

Network Sampler/Process Analyzer

This example was used with an ATAGO serial glucose refractometer. Miniature CIP unit with air blow for sample isolation performed. Analysis onboard for feed model evaluation; or Feed pump rate control. The yellow pump is the sample pump, the other two are the wash and rinse solutions. Unit is shown in Plan view, all pumps mounted in a horizontal plane sloped to drain. Integral power supply for the ATAGO unit.

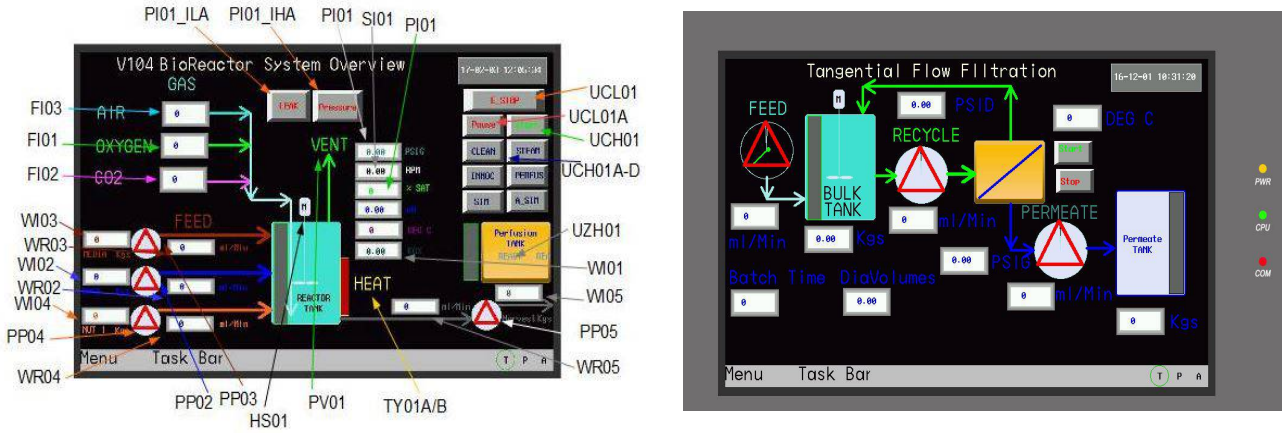

Figure 8a. Typical Slave database links to client graphic application for a Bio-Reactor; at right is for a TFF unit.

Above are conventional industrial visualization clients, TELEZ also supports a RESTful Modbus client for cloud apps on Mobile devices.

Figure 9. 200L Concentration/UF/DF

Ultra-Filtration Unit/Filter Analyzer

Controller with sequential Dia-filtration and concentration calculations.

- TMP control /back-pressure control
- Feed and Permeate pumps built in and 1-5V external analog Watson-Marlow pump for Recycle.
- Filter capacity evaluation from experimental online data. Correlation of Vmax on a mass basis.
- A variety of pressure sensors are supported.
- Sanitary reusable or Disposable system configurations. Lab scale units with holding tanks from 1L to 200L.
- Reversible pumps with air-blow cycles to minimize hold-up
- For Size reference. Shown is an e-Lab ATMega2560 with a WizNet 5100 Ethernet module.
- 10” HMI with USB stick data, and Ethernet.
- External serial scale module is mounted on the rear of the tripod holder for 600 Kg Tank capacity.

Process Equipment:

This unit is a network capable filter controller for UF, it has onboard predictive capability for calculation of filter capacity given allowable pressure drop. This calculation expedites development or for online filter diagnostics. The unit can store data locally to SD card either on the HMI or on the control processor. Stepper drive pumps shown here provide for precise rate control. Various scale interfaces (serial or analog) are available for mass balance calculations. The same unit used in conjunction with your TFF, UF, or dead end filter system adds diagnostic functionality online without changing the hardware or controls you have. This unit uses either disposable or conventional pressure sensors. The light-bar is a quick indicator for unit operational state and key interlock or process alarms at a glance. The unit does have an optional audible alarm. The unit is IP 54 but could be IP63 with larger sized enclosure due to pump heat loads.

Communications/IoT:

This HMI is MODBUS TCP or substitue S7-1200 Profinet, HMI optional remote mounted, or run and access it from your laptop; This client started production with USBoperation and expanded to remote HMI. The unit can store data local to SD card either on the HMI or on the control processor.

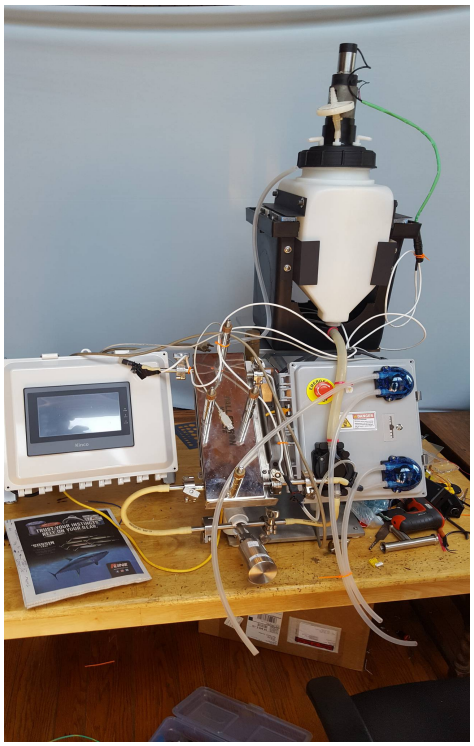

Figure 10. 10L integrated concentration Tank with incline for drainage.

Ultra-Filtration with product Concentration Tank

Filtration controller with sequential Dia-filtration and concentration calculations.

- A variety of pressure sensors are supported.
- Lab scale units (10L shown). Conical bottom.
- Upper dome pump is Dia-filtrate feed.
- Lower dome pump is permeate.
- The black pump is the recycle pump (at the low point) is reversible for complete drainage.
- Stepper driven pinch valve provides back pressure measurement via a disposable pressure sensor.
- Filter inlet pressure is measured using ANDERSON mini sanitary transmitter; shown at the low point filter inlet line in MARPRENE high-pressure tubing.
- Integrated Stainless frame for geometry and drainage assurance.
- Inclined Pump enclosure for ergonomics
- Separate HMI enclosure for remote mounting

Process Equipment:

The unit integrates the Holding Tank for calculation of final product concentration too. Four high-resolution load cells with dedicated amplifiers weigh recycle tank. Weight based feedback of Dia-filtrate feed and permeate via load cells expandable onboard the filter controller for mass balance calculations and filter performance profiling. Double containment with wind shielding is provided by the black tank support structure for spill prevention, and accurate weight measurement. The load cells integral to the tank containment vessel, the slave processor and amplifiers also move with the tank and support; the load cell processor powered via the main processor enclosure as well as the agitator drive with tachometer feedback.

C*ommunications – IoT:*

- These enclosures are corrosion resistant/ and water proof plastic for economy.
- *S*tainless steel if you want.
- SainSmart ATMega2560 Hardwired Ethernet with waterproof connector or Teensy 3.6.
- Toshiba 6600 Stepper drives to 6A, or larger drives via RS485
- 16-bit Analog inputs.
- KINCO 7” industrial HMI NEMA 4, IP63.

Compact Bio-Reactor Controls (Process Service Module)

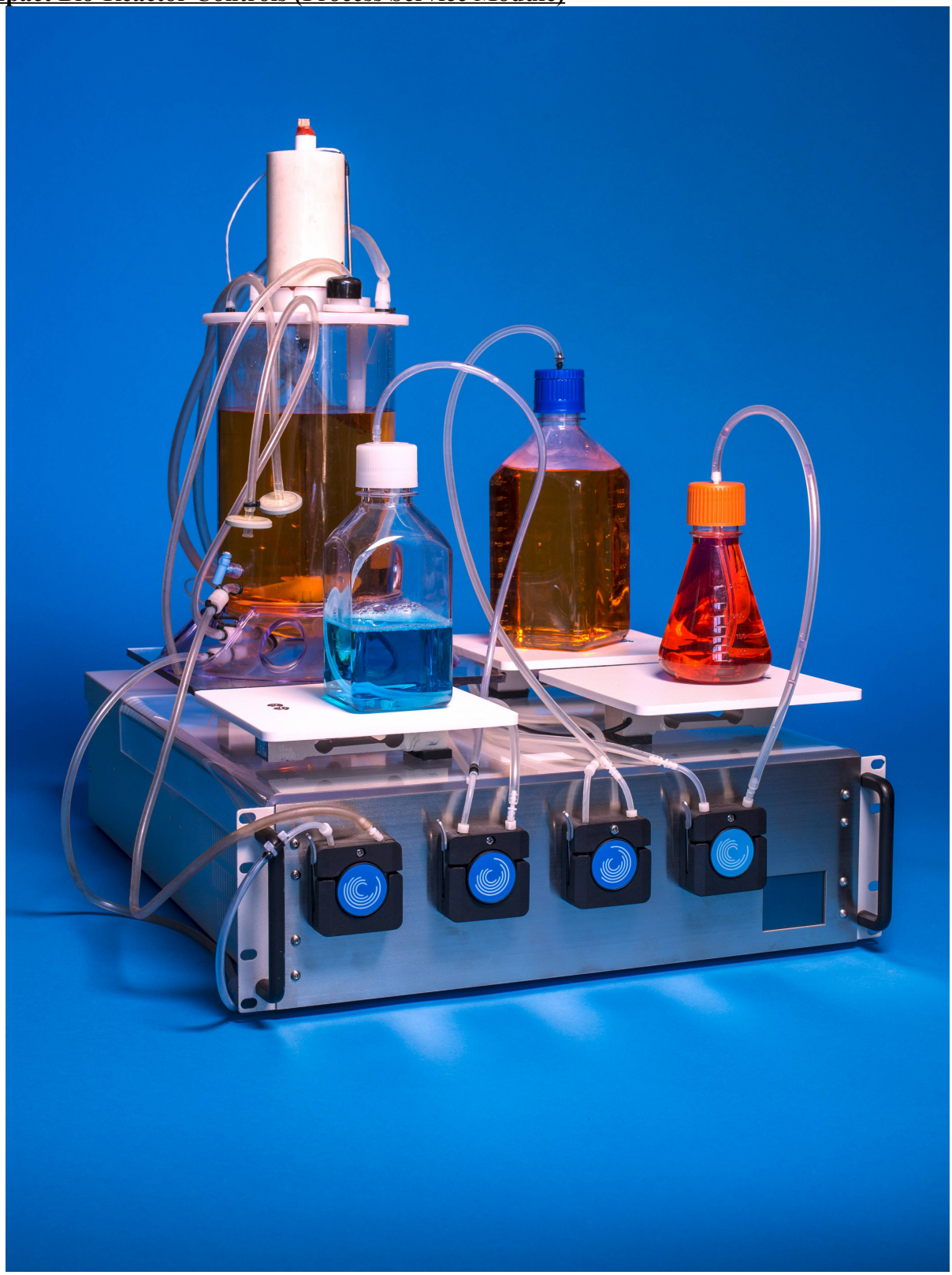

Figure 11. Process Service Module – Stirred tank or other reactor configurations are possible.

Process Equipment:
Bio-Reactor controller or other Process Service Module Shown above. This controller provides operational management of liquids and gasses for environmental and feeding controls for your small scale-up development. Full process instrumentation interface includes:

- Not limited to Stirred tank, customer agitation systems can be controlled or interfaced.
- Can hybridize with other systems to provide existing system enhancement or extension
- Built in Stepper drive Pumps for 7 $\log_{10}$ of pump rate control
- Modular pumping and Mass systems are local network capable for swap out to change the scale of the reactor. Slave pump service modules expand to deliver more fluids.
- External User pumps supported or expandable 3U pump modules can be stacked..
- Modular RS485 network for Gas mass flow-meters allows the same unit electronics to be quickly redeployed at a different scale (AliCat).
- Back pressure valve via stepper pinch valve or Solenoid.
- Dual Element RTD , split range heating and cooling with Time Proportional on/off or analog outputs.
- Optical pH and DO serial interface capable with photo-bleaching compensation or wet probes
- Pressure measurement disposable or reusable Pressure sensors

A 4U unit for larger pumps and high-pressure outputs for blending operations or chromatography to 50 PSI liquid delivery is under development for large scale production. Patented Pump technology for High-pressure peristaltic pumping with reduced pulsation for accurate blending at moderate chromatography pressures. That technology enables disposable chromatography for some clients at 3 LPM or below pump rates.

Communication – IoT:
Network configurable operation.
Network configurable operation. Optional cellular device communication. Cellular cloud phone capable interface with onboard LINUX file-server for true IoT point of existence. TELEZ system architecture can offer a remote cloud interface. Enabling operation remotely or for “Bring your own Device” BYOD operation of equipment. In this way an operator or technician using the equipment can remain focused even when not at the local HMI.

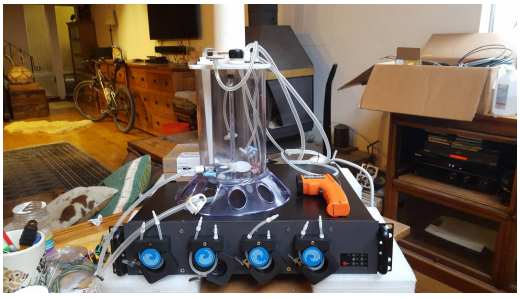
Figure 12. 2U disposable configuration.

For a variety of cellular expression systems. Modular design allows the expansion of pumping and gas contacting systems to suit the user.

- OPEN SOURCE code allows the user to have DIRECT access to the control algorithms for modification and enhancement.
- Open modular design allows rapid integration with existing systems that are industrial network capable.
- Modular pumping and integrated Mass Balance capable in real time.
- Integration with MASS SPECTROMETER data for feed strategy,off-gas analysis, or perturbation analysis onboard.

Multi-Channel Filling Unit/Bending (TELEZ - ARM stepper or DC Servo slaves)

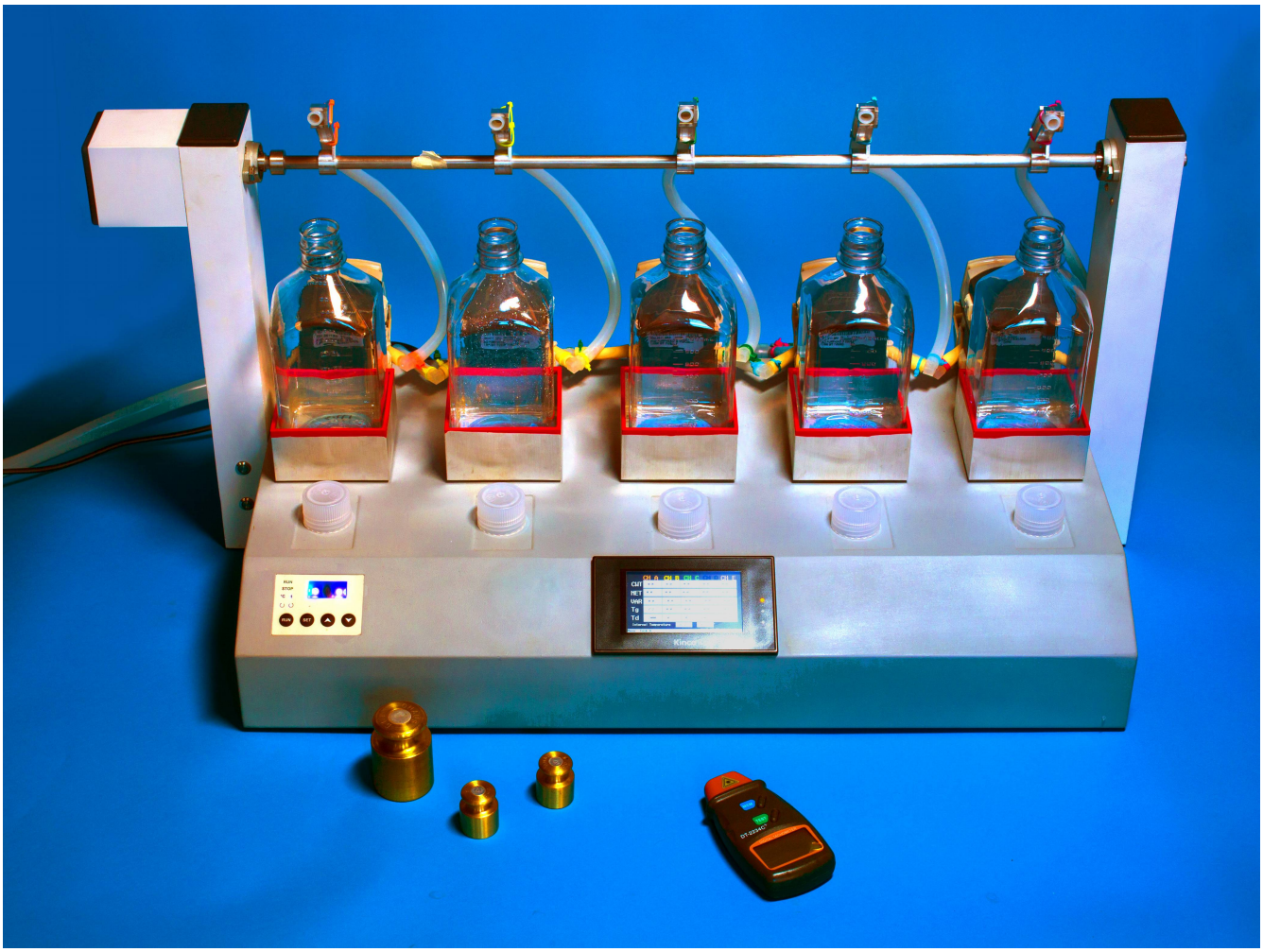

Figure 13. DC SERVO unit - 5 channel filler, steppers are better.

Process Equipment:

Intended for the small filling to mid range semi automatic operations. Size and geometric configuration suitable for insertion into a standard laminar flow air hood for hygienic filling. Configurations suitable for Multichannel sample or product archive. Design adaptable to a variety of Container geometries and capacities up to Nalgene 2015-1000 configurations. Container verification and 100% check-weigh. 0.1 gram resolution standard. High speed fills with 1L in 30 seconds for up to five channels. Either DC servo or Stepper driven pumps. Shown are double stacked Watson-Marlow D313 and a variety of Pump manufacturers is supported.

Communications – IoT:

Network operable, touch screen interface, and also single foot-switch operation capable. High-pressure pump systems are available to 50 PSIG. Either DC servo or Stepper driven pumps. A variety of Pump manufacturers is supported. Network capable for data acquisition or control/configuration. Fuzzy logic self-optimization of filling parameters is available. It is required for a DC servo unit. This unit can be reconfigured into a blending/gradient capable controller.

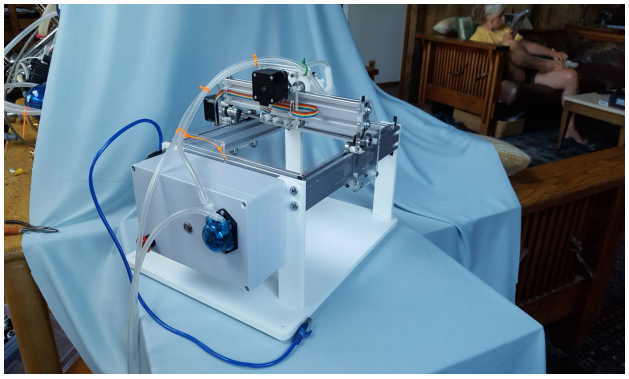

Figure 14. Setup for 50 ml centrifuge tubes in a rack.

Sample Archiver
Available in Cartesian or polar coordinate configurations. Sample pre-processor available for hygienic or sterile sampling. Local data archive capability. Immediate data analysis of sample set can be conducted onboard for fraction collection or product chemistry measurements.

Process Equipment:
An Auto-sampler to put right at the test unit or in the refrigerator. Fast loop pump for remote delivery of a fresh sample to the sample pump. The unit supports inline sensor arrays that can be acquired during sampling in the fast or slow loop as appropriate to make data available on the Network. If more than 3 stepper motors are required the control enclosure would require a larger size than pictured (8”x4”x3”) for additional slave axis controllers and larger power supply.

- Sample harness is convenient, cheap, and disposable of bio-compatible silicone or other material.
- Optionally, irradiate harnesses, add UV sterile barriers for hygienic sampling and put it in your hood.
- Sanitary polyethylene base cutting board material with interchangeable elevation posts
- Snap on locators on the cutting board to customize for your container dimensions.
- A waste station location is optional.
- For very small containers optional position feed back on X and Y position is integrated into the stepper module for local slave position feedback.
- TFF in fast loop possible.
- Dispose of the sample pump assembly or snap a new tubing harness into the unit for reuse. Other sample pumps including stepper drives are available.
- Optionally, a Z axis can be added to this unit for septum piercing in a hood.

Communications – IoT:
Optionally, 16-bit analog inputs can be added for analog measurements.
Configurable over the network for array locations, sample order, volumes, and schedule.
Network Data collection of sample parameters over Ethernet.

Continuous Flow through Sterilizer (HTST)
Sanitary Tubular heat Exchangers for heat economizer, direct steam injectors or heat exchanger for HTST operation. Industrial Network configurable/Monitoring. The design is scalable from 100ml/min to 10 LPM with minor equipment selection/changes. Heat up sequential operation and diversion to recycle is automated. Recipe driven operation. Solids content tested. Design velocities are evaluated for uniform contact times.

Figure 15. S7-1215 mounted with see through for I/O status. IP63

Pictured on the previous page, a Siemens S7-1200 PLC is utilized for continuous, batch process, and control I/O operation. A Profibus I/O network for Valves and Utility I/O saves wiring costs and provides easy expand ability. Possible to use an Allen Bradley L33ER controller if desired.

Process Equipment:
From a process point of view the unit does use and recover rejected heat from the process stream from cooling operations to preheat the process, direct steam injection or Heat Exchanger heating to HTST temperatures is dependent on process needs. A final cool-down Exchanger can be utilized to bring the HTST stream to process temperature. This unit is also capable of feed-forward control to maintain operations for a variable feed load and can provide process pre-alarm, alarm, and interlock diversion of feed or shutdown if desired.

Communications – IoT:
TELEZ added as a Slave Bridge. This design facilitates the addition of user specific instrumentation or methods and can selectively make them available remotely or for “Bring your own Device” BYOD operation of equipment. In this way, an operator or technician using the equipment can remain focused even when not at the local HMI or overnight away off-site.