LCLS II–
Experiment Systems
Vacuum Controls Architecture

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LCLS-II Vacuum Controls Systems

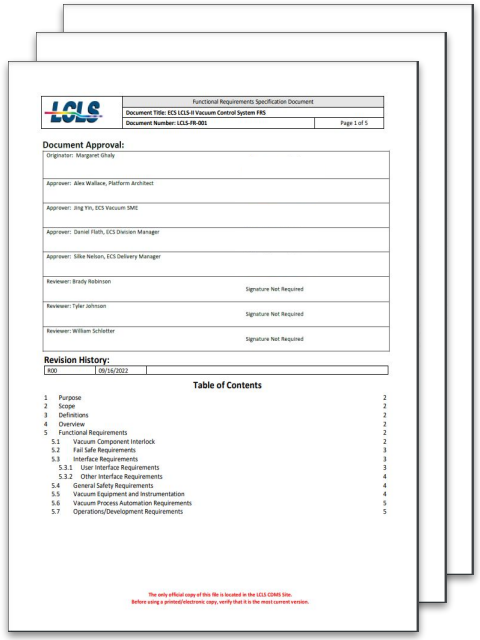
Vacuum Controls Requirements

- Physics Requirement Documents
  - Preserve vacuum
  - Preserve vacuum components
  - Ability to controls and monitor vacuum systems/devices remotely
- Controls FRS-ESD
  - Maintain high availability
  - Modular PLC code and SCADA code libraries
  - Standard hardware and interfaces
  - Include testing and troubleshooting through all phases of the system's life cycle
  - Enable straightforward and timely upgrades and deployment
  - Record vacuum events

LCLS-II Vacuum Controls System - Architecture

Time for an upgrade.

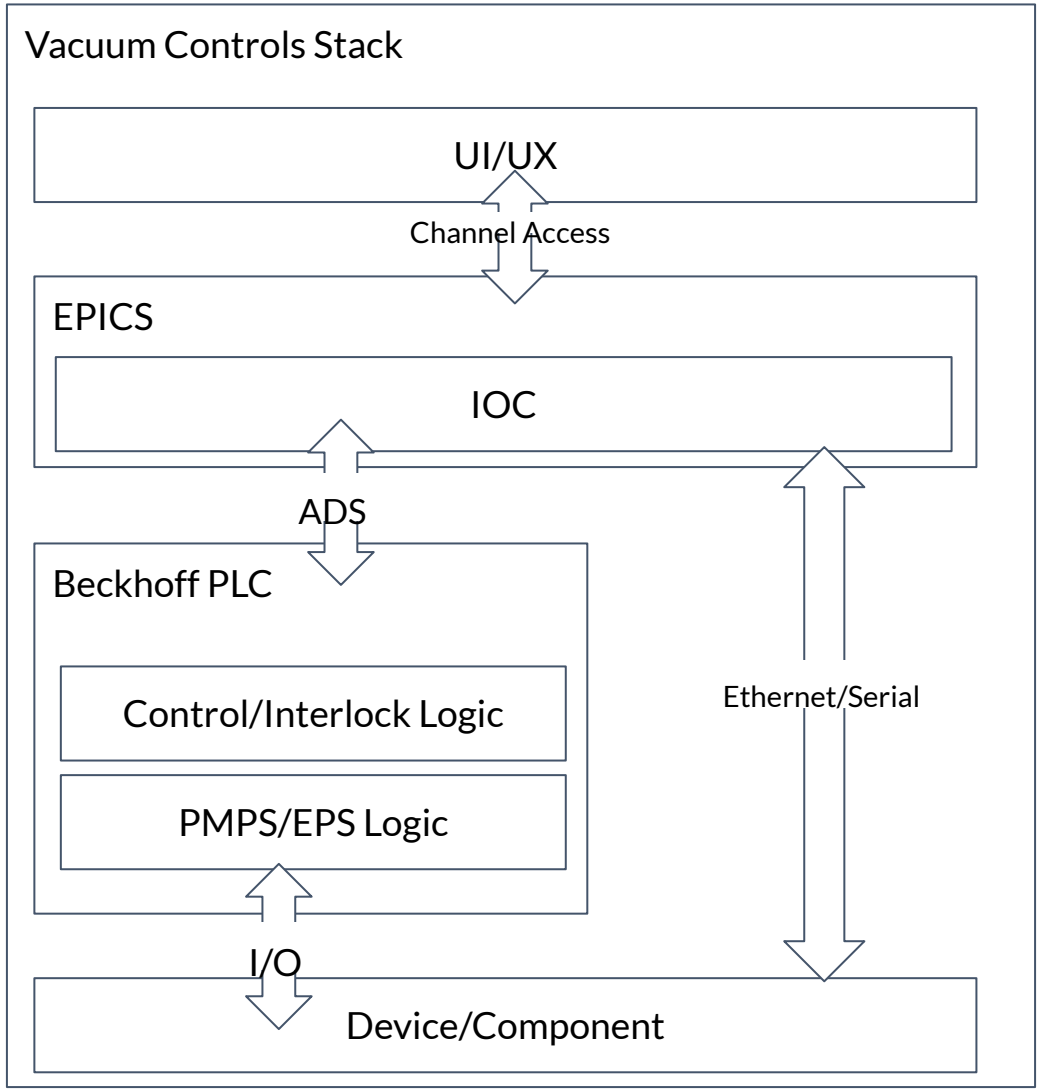
- Experiment system vacuum controls architecture:
  - Informs all phases of a vacuum system **lifecycle**
  - With a **full stack** of integrated software and hardware
  - Complement of software and hardware **tools**
  - Enables a **straightforward** delivery of vacuum controls system
    - Development and Deployment
    - Testing and Checkout
  - **Beyond** the LCLS-II project



LCLS-II Vacuum Controls Systems - Architecture

Experiment Controls full stack integration.

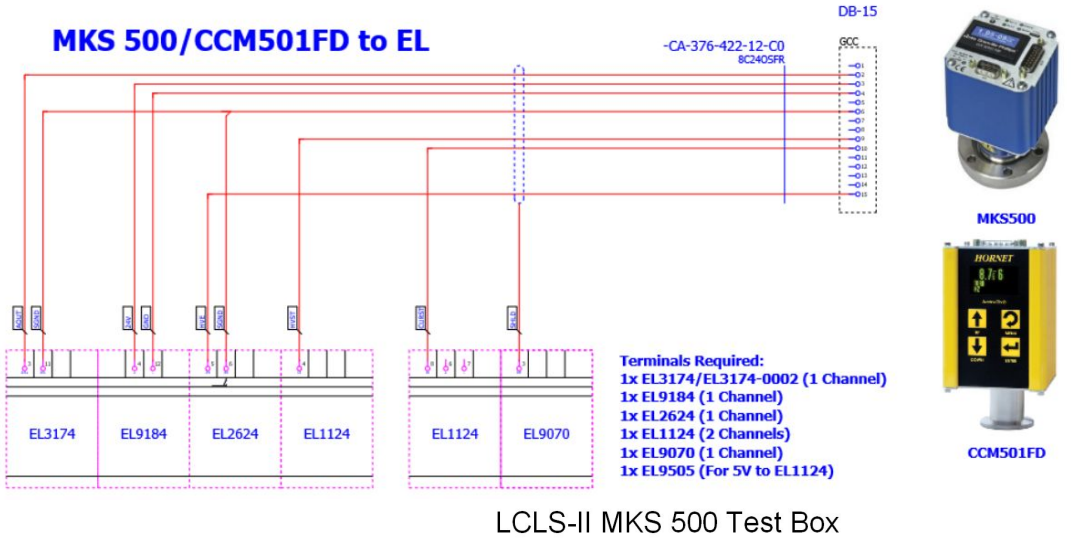
- UI/UX screens
- Ophyd devices
- EPICS interface
- Beckhoff Communication interface with EPICS (ADS)
- Beckhoff PLC – Software libraries
- Device/Controller interface I/Os



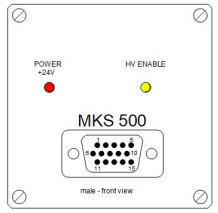
Device Component - IO

It all starts at the connector.

- Cable design
  - Cable type
  - Connector
  - Pinouts
  - Fabrication information
- Standard CAD Macro
  - Cable number
  - Signals
  - Termination
  - I/O terminals
- Test Box
  - Verify cables fabrication
  - Verify termination

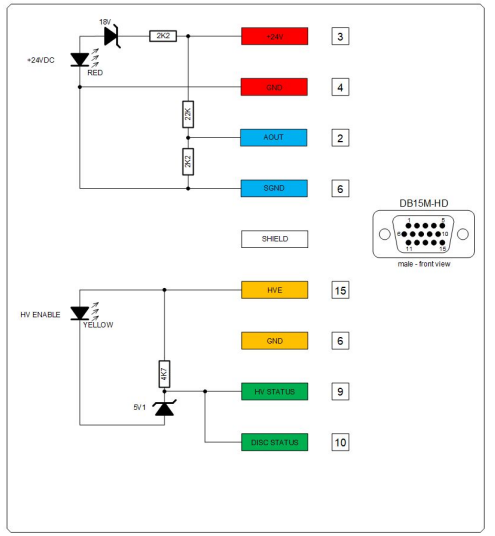


LCLS-II MKS 500 Test Box



Test procedure:

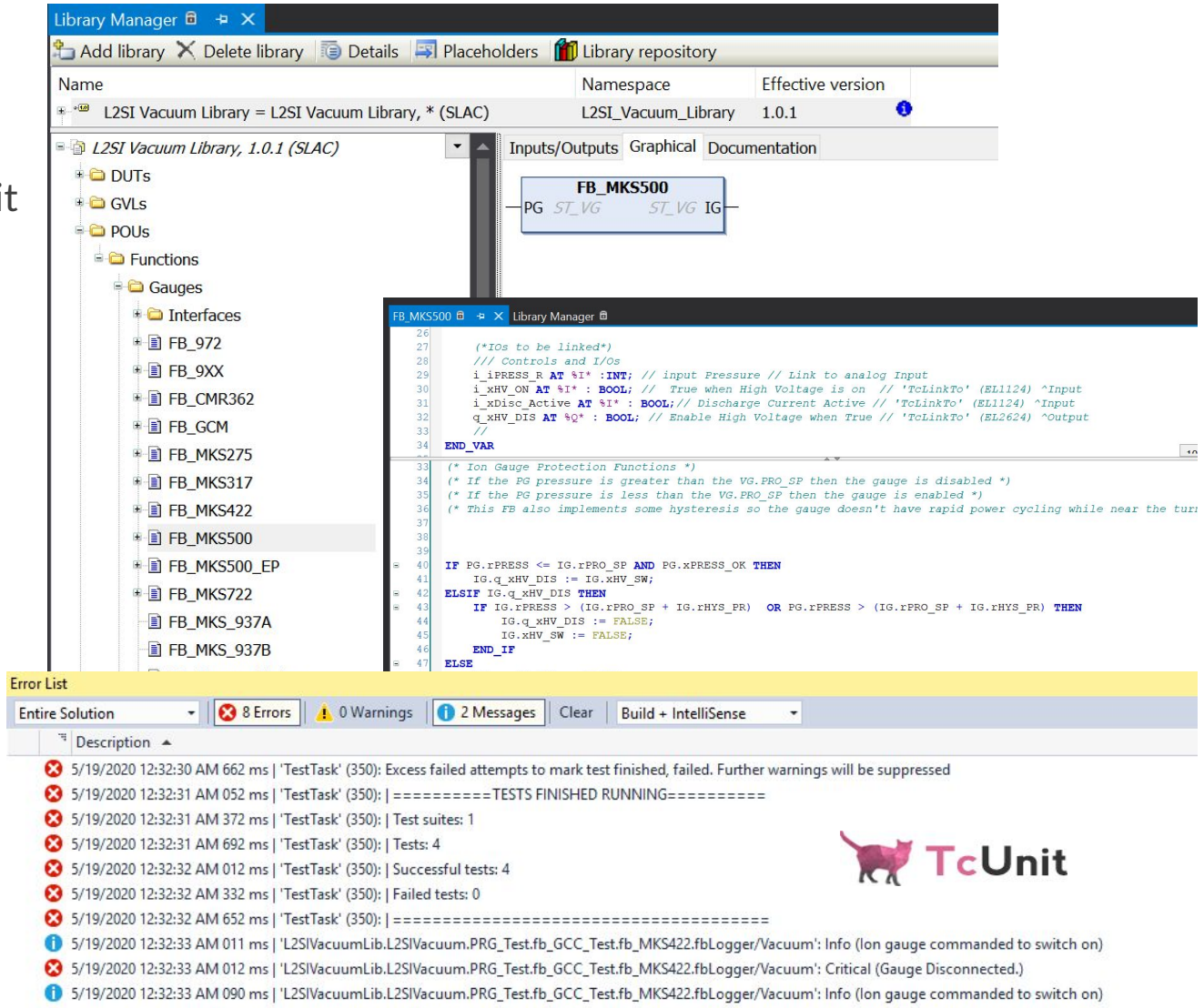
- Connect the cable in the Test Box.
- +24V LED should be lit.
- Enable HV from PLC.
- HV STATUS and DISC STATUS should read HIGH.
- Analog Pressure should read +2.4 VDC.



Vacuum Library

Complete TcLibraries code with unit tests.

- Basic operational functionality and Interlocks are implemented in the PLC
  - Bundling data and logic together as a single unit
  - Structure includes all device PV/data
  - All I/Os definitions
  - Protection/Run Logic, MPS
  - PLC variable tagging
  - Logging.
- Unit Testing
  - Ensures any modifications to existing device didn't break basic functionality and interlocks
  - Reduce deployment time for future library releases



Vacuum Library- Logging

Vacuum and device state events are recorded.

- Logging functionality is fully integrated in the library code
  - Messages can be logged every PLC cycle
  - Device state changes
  - Actions
  - Interlock events

FB_MKS909 | FB_MKS422.ACT_Logger* | FB_MKS500 | FB_901_ECAT.ACT_Logger

```
// ILK logger
IF (IG.xLog) THEN
    IF NOT IG.xILKOk AND NOT IG.q_xHV_DIS THEN
            fbLogger(sMsg:='Lost external interlock while gauge was on.', eSevr
    END_IF
    // Log Action
    tAction(CLK:=  IG.xHV_SW);
    IF tAction.Q THEN fbLogger(sMsg:='Ion gauge commanded to switch on', eSevr:

    //STATE Logger
    IF ePrevState <> IG.eState THEN
          CASE IG.eState OF
            ValidHi:
                fbLogger(sMsg:='Gauge pressure valid high.', eSevr:=TcEventSeve
            ValidLo:
                fbLogger(sMsg:='Gauge pressure valid low.', eSevr:=TcEventSever
            Valid:
                fbLogger(sMsg:='Gauge pressure valid.', eSevr:=TcEventSeverity.
```

Logged Events

0 Alarms | 1000 Messages | Verbose | 1033

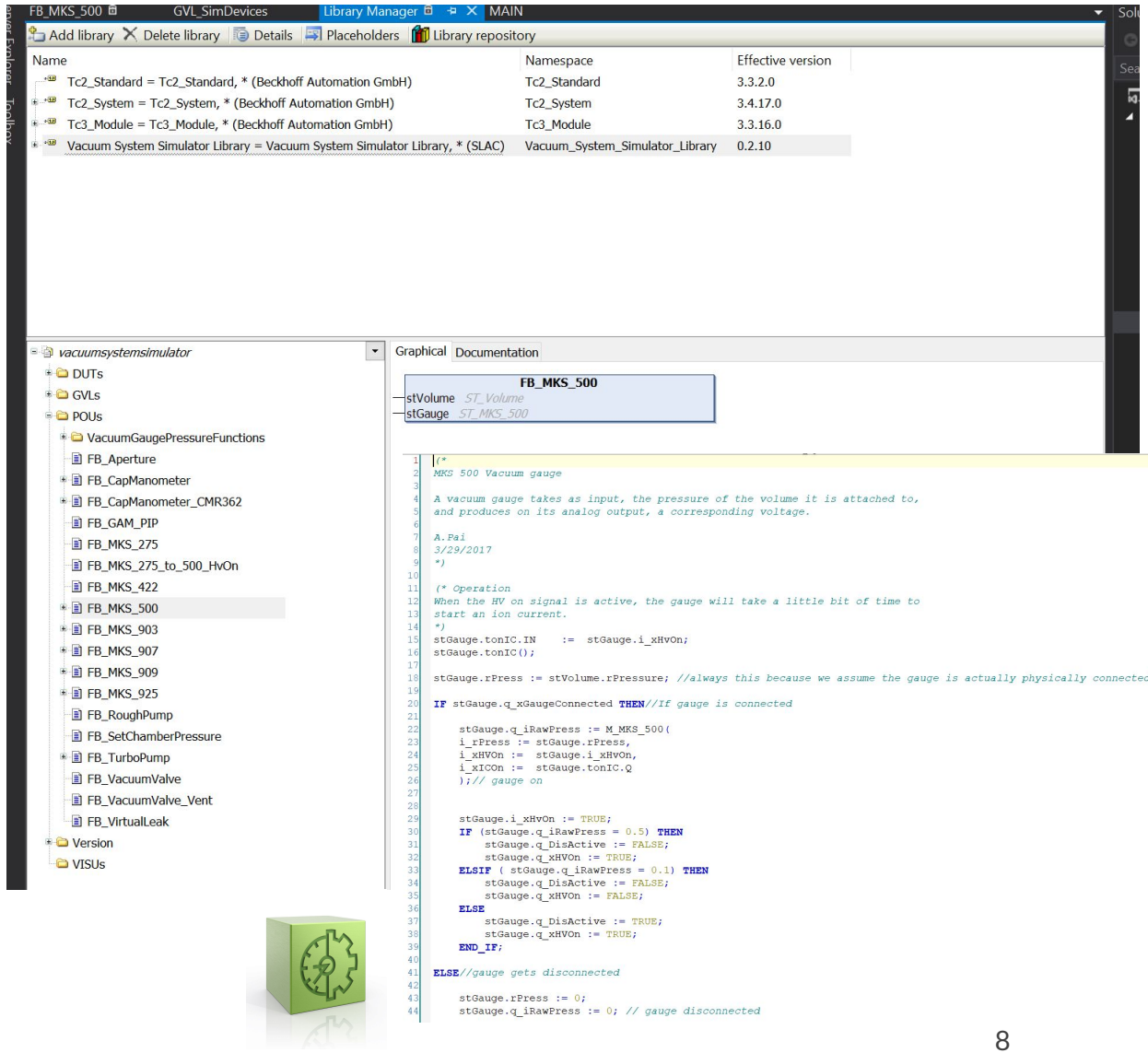
Severity Level	Event Class Name	Event Id	Event Text	Source Name	Time Raised	Time Cleared	Time Confir
Info	Log event	3	Info (Valve set to Close.)	plc_kfe_xgmd_vac.plc_kfe_xgmd_vac.GVL_Devices.VGP_50.fbLogger/Vacuum	10/5/2021 6:39:04.958 AM		
Info	Log event	3	Info (Valve commanded to move)	plc_kfe_xgmd_vac.plc_kfe_xgmd_vac.GVL_Devices.VGP_50.fbLogger/Vacuum	10/5/2021 6:39:04.957 AM		
Critical	Log event	0	Critical (Pump stopped.)	plc_kfe_xgmd_vac.plc_kfe_xgmd_vac.GVL_GMD.fb_EM2K0_XGMD_PTM_30.fbLogger/Vacuum	10/4/2021 12:47:04.527 PM		
Critical	Log event	0	Critical (Pump Fault.)	plc_kfe_xgmd_vac.plc_kfe_xgmd_vac.GVL_GMD.fb_EM2K0_XGMD_PTM_30.fbLogger/Vacuum	10/4/2021 12:47:04.327 PM		
Critical	Log event	0	Critical (Pump Lost Alarm OK bit)	plc_kfe_xgmd_vac.plc_kfe_xgmd_vac.GVL_GMD.fb_EM2K0_XGMD_PTM_30.fbLogger/Vacuum	10/4/2021 12:47:04.317 PM		
Info	Log event	3	Info (Pump starting.)	plc_kfe_xgmd_vac.plc_kfe_xgmd_vac.GVL_GMD.fb_EM2K0_XGMD_PTM_30.fbLogger/Vacuum	10/4/2021 12:47:04.127 PM		
Info	Log event	3	Info (Pump running.)	plc_kfe_xgmd_vac.plc_kfe_xgmd_vac.GVL_GMD.fb_EM2K0_XGMD_PTM_30.fbLogger/Vacuum	10/4/2021 12:43:36.969 PM		

2023-06-24 10:29:12	Info (Gauge pressure valid.)	plc_kfe_gatt.plc_kfe_gatt.GVL_Devices.fb_AT1K0_GAS_GCC_140.fbLogger	1
2023-06-24 10:29:10	Info (Gauge pressure valid.)	plc_kfe_gatt.plc_kfe_gatt.GVL_Devices.fb_AT1K0_GAS_GCC_130.fbLogger	1
2023-06-24 10:29:09	Info (Ion gauge commanded to switch on)	plc_kfe_gatt.plc_kfe_gatt.GVL_Devices.fb_AT1K0_GAS_GCC_140.fbLogger	1

Vacuum Library- Simulator

Testing, testing, testing.

- Simulation Library
  - Each vacuum device has its own simulation function block
    - All I/Os definitions (inverted)
    - Simulate the device functions
    - Simulates vacuum volumes
- EtherCAT Simulation
  - Connect the PLC to a simulation computer.
  - EtherCAT features on the simulation computer are modeled.
  - No additional reconfiguration needed



EPICS Interface

Automatic generation of db files from PLC.

- ADS deploy and Pytmc
  - SLAC-defined Pytmc pragmas to tag variables and data structures of the PLC code
  - Automates and simplifies accessing PLC variables through EPICS
  - EPICS DB records are generated automatically
  - ads-deploy wraps the above tool to generate a templated IOC and ready it for usage

- EPICS device drivers
  - Stream Device and Modbus
  - Configuration variables
  - Device meta-info
  - Long-term device status variables

```
15      {attribute 'pytmc' := '
16      pv: AT_VAC;
17      io: i;
18      field: ZNAM FALSE;
19      field: ONAM TRUE;
20      '}
21      xAT_VAC: BOOL;
22      {attribute 'pytmc' := '
23      pv: PRESS_OK;
24      field: ZNAM OFF;
25      field: ONAM ON;
26      io: i;
27      '}
28      xPRESS_OK: BOOL;
29      {attribute 'pytmc' := '
30      pv: STATE;
31      field: ZRST Off;
32      field: ONST GaugeDisconnected;
33      field: TWST OoR;
34      field: THST PressInvalid;
35      field: FRST Starting;
36      field: FVST Valid;
37      field: SVST ValidHi;
38      field: SVST ValidLo;
39      io: i;
40      '}
41      eState  :   E_PressureState;
42      (* EPICS Controls *)
43      {attribute 'pytmc' := '
```

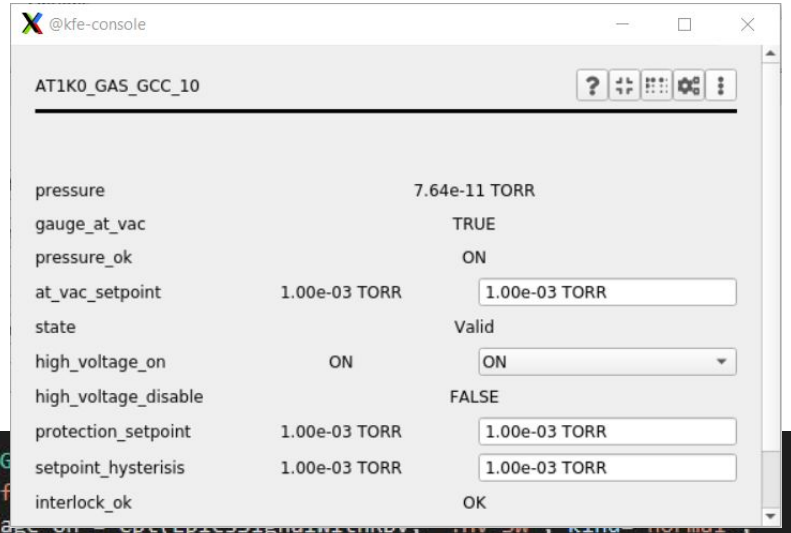
```
(* EPICS Controls *)
    {attribute 'pytmc' := 'pv: OPN_SW field: ZNAM CLOSE field: ONAM OPEN io: io '}
    pv_xOPN_SW   : BOOL;
    {attribute 'pytmc' := '
    pv: ALM_RST
    io: o
    '}
    pv_xAlmRst   : BOOL;
```

```
record(bo, "EM1L0:GEM:VGC:10:OPN_SW"){
  field(ZNAM, "CLOSE")
  field(ONAM, "OPEN")
  field(DTYP, "asynInt32")
  field(OUT, "@asyn($(PORT),0,1)ADSPORT=851/GVL_Devices.GEM1_VGC_10.iq_stValve.pv_xOPN_SW=")
}
```

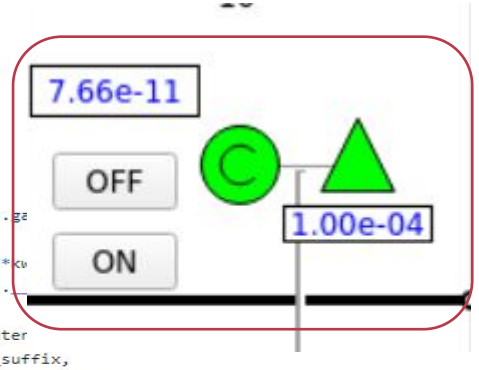
UI/UX - Ophyd and PyDM

Automatic generation of detailed engineering screens.

- Ophyd
  - Typhos uses ophyd objects to auto-generate device engineering screens
- PyDM Widgets
  - Widget stylesheet customizing the appearance of the widget based on the values of a number of PVs




```
227     """
228     _interlock_suffix = ":ILK_OK_RBV"
229     _state_suffix = ":STATE_RBV"
230     _readback_suffix = ":PRESS_RBV"
231     _command_suffix = ":HV_SW"
232
233     NAME = "Cold Cathode Gauge"
234     EXPERT_OPHYD_CLASS = "pcdsdevices.ga
235
236     def __init__(self, parent=None, **kw
237         super(ColdCathodeGauge, self).__
238             parent=parent,
239             interlock_suffix=self._inter
240             state_suffix=self._state_suffix,
241             command_suffix=self._command_suffix,
242             readback_suffix=self._readback_suffix,
243             readback_name='pressure',
244             **kwargs)
245         self.icon = ColdCathodeGaugeSymbolIcon(parent=self)
246         self.readback_label.displayFormat = DisplayFormat.Exponential
247
```




```
class GCCPLC(G
    """Class f
    high_voltage_on = Cpt(EpicsSignalWithRBV, ':HV_SW', kind='normal',
                          doc='command to switch the high voltage on')
    high_voltage_disable = Cpt(EpicsSignalRO, ':HV_DIS_DO_RBV', kind='normal',
                               doc=('enables the high voltage on the cold '
                                    'cathode gauge'))
    protection_setpoint = Cpt(EpicsSignalWithRBV, ':PRO_SP', kind='normal',
                              doc=('Protection setpoint for ion gauges at '
                                   'which the gauge turns off'))
    setpoint_hysterisis = Cpt(EpicsSignalWithRBV, ':SP_HYS', kind='config',
                              doc='Protection setpoint hysteresis')
    interlock_ok = Cpt(EpicsSignalRO, ':ILK_OK_RBV', kind='normal',
                       doc='Interlock is ok')
    auto_on = Cpt(EpicsSignalWithRBV, ':Auto_On', kind='config',
                  doc=('Setting to automatically turn on the gauge when the'
                       'reference gauge pressure is below protection '
                       'setpoint'))
    autoOn_countdown = Cpt(EpicsSignalRO, ':AutoOn_timer_RBV', kind='normal',
                           doc='timer count down to turn on the gauge ')
```

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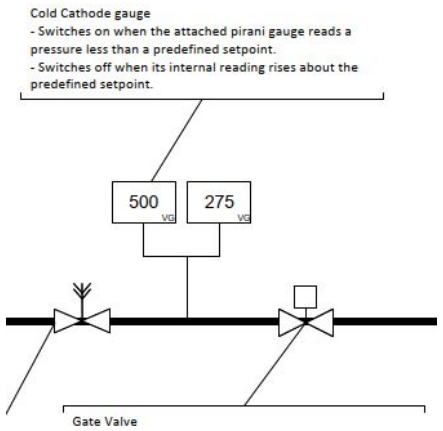
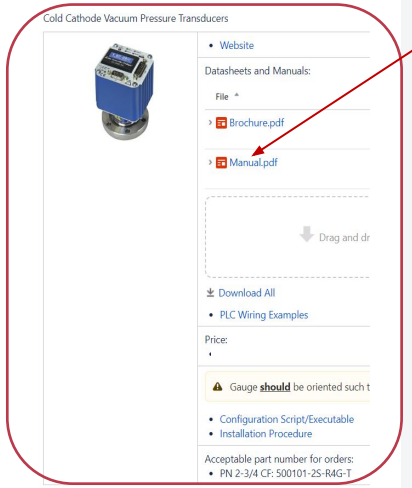
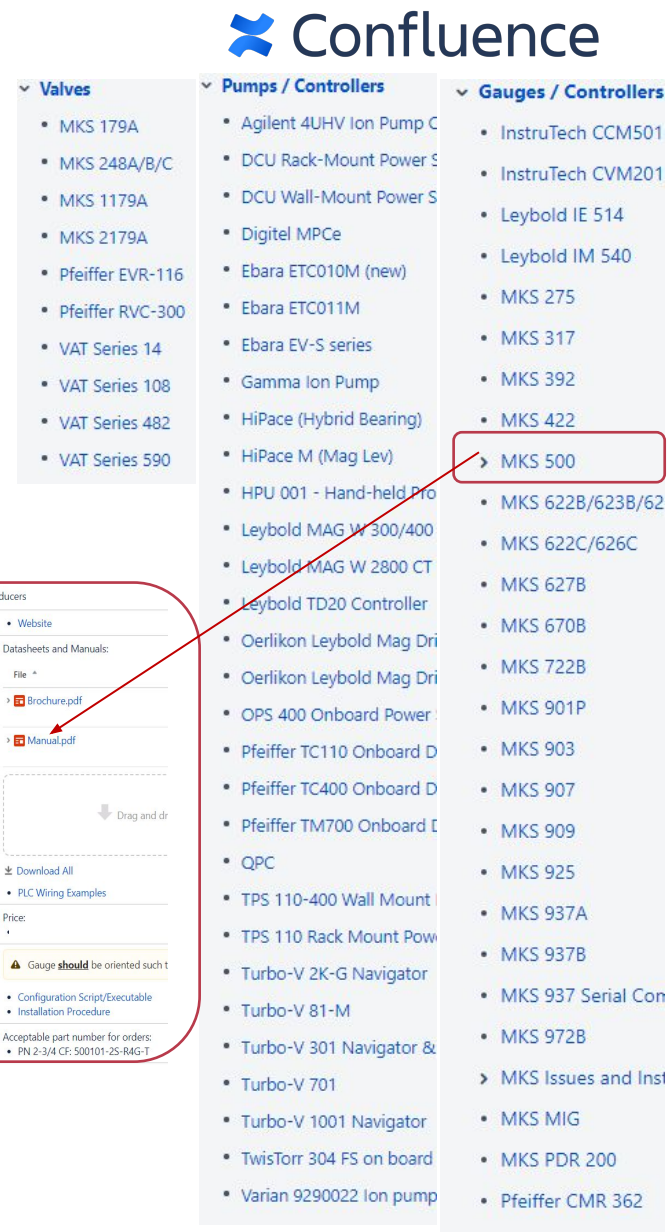
LCLS-II Vacuum Controls Systems - Architecture

Standardisation.

- Supported Device List (SDL)
  - Extensive list of vacuum devices
  - Fully integrated across the stack
  - Configuration Scripts
- Vacuum Design templates

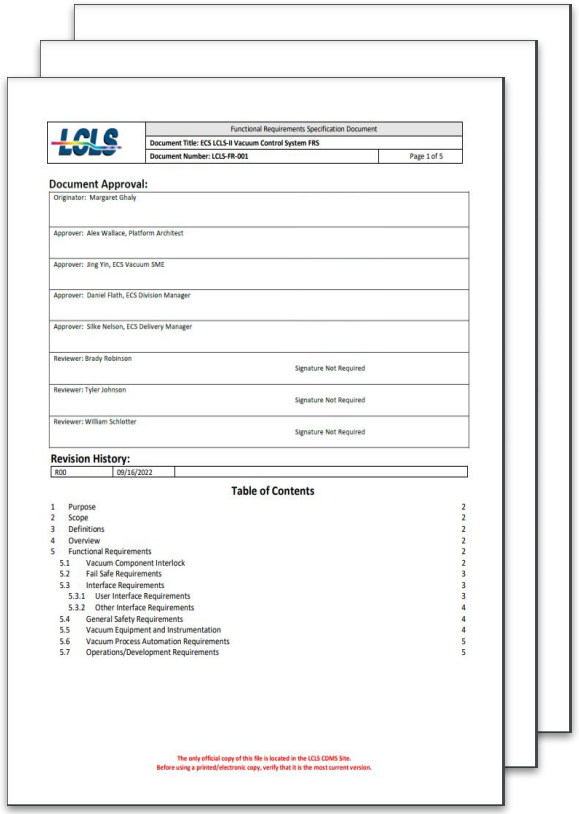






LCLS-II Vacuum Controls Systems - Architecture

Beyond LCLS-II.



Functional Requirements Specification Document

Document Title: ECS LCLS-II Vacuum Control System FRS

Document Number: LCLS-FR-001 Page 1 of 5

Document Approval:

Originator: Margaret Ghaly

Approver: Alex Wallace, Platform Architect

Approver: Jing Yin, ECS Vacuum SME

Approver: Daniel Flath, ECS Division Manager

Approver: Silke Nelson, ECS Delivery Manager

Reviewer: Brady Robinson — Signature Not Required

Reviewer: Tyler Johnson — Signature Not Required

Reviewer: William Schlotter — Signature Not Required

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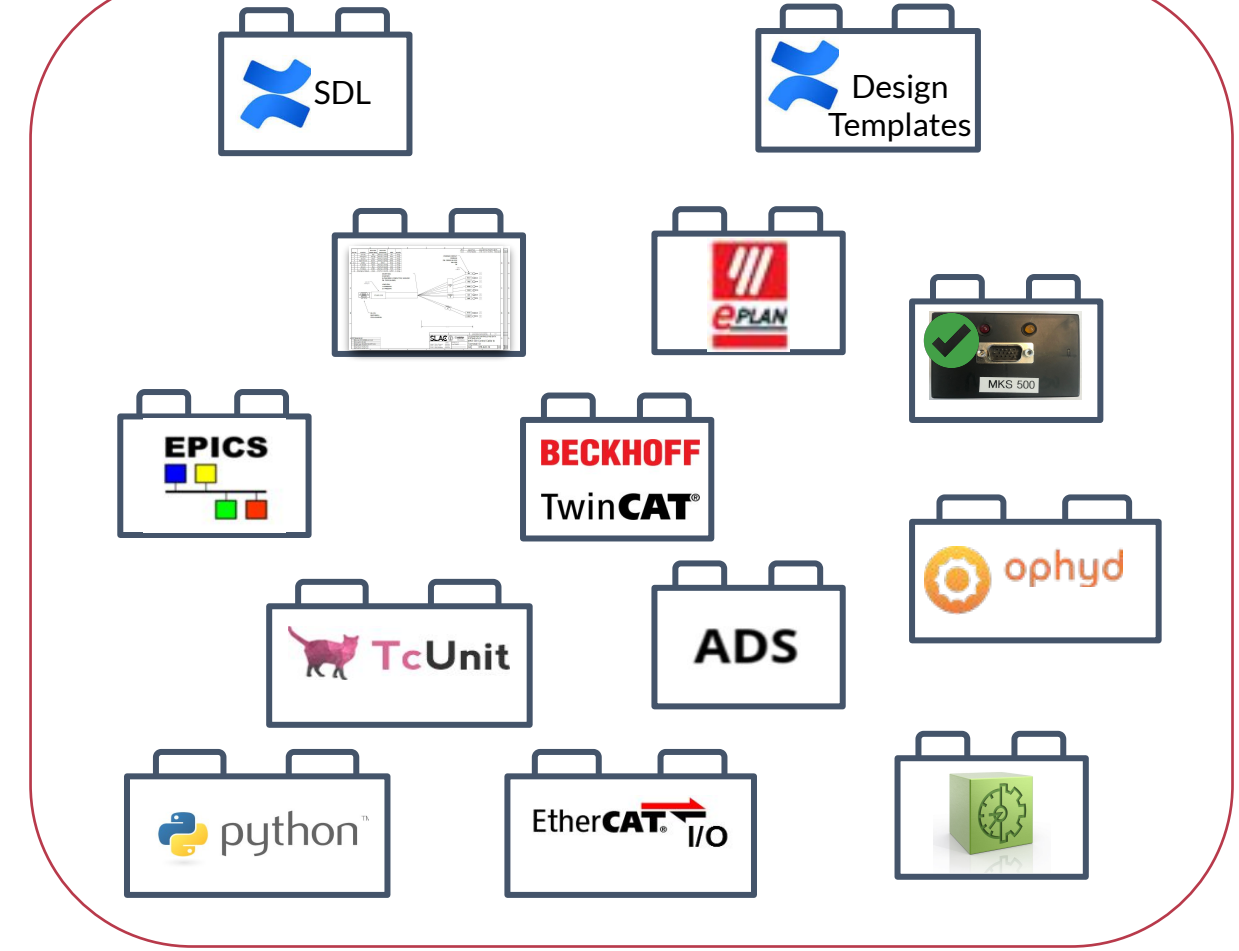

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