LIGO

WELLESLEY

Developing Remote Controls for the Motorized Polarization Controller in LHO's Arm Length Stabilization System

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SURF Final Presentation
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Outline

I. Arm Length Stabilization

II. Motorized Polarization Controller

III. TwinCAT-EPICS-MEDM System

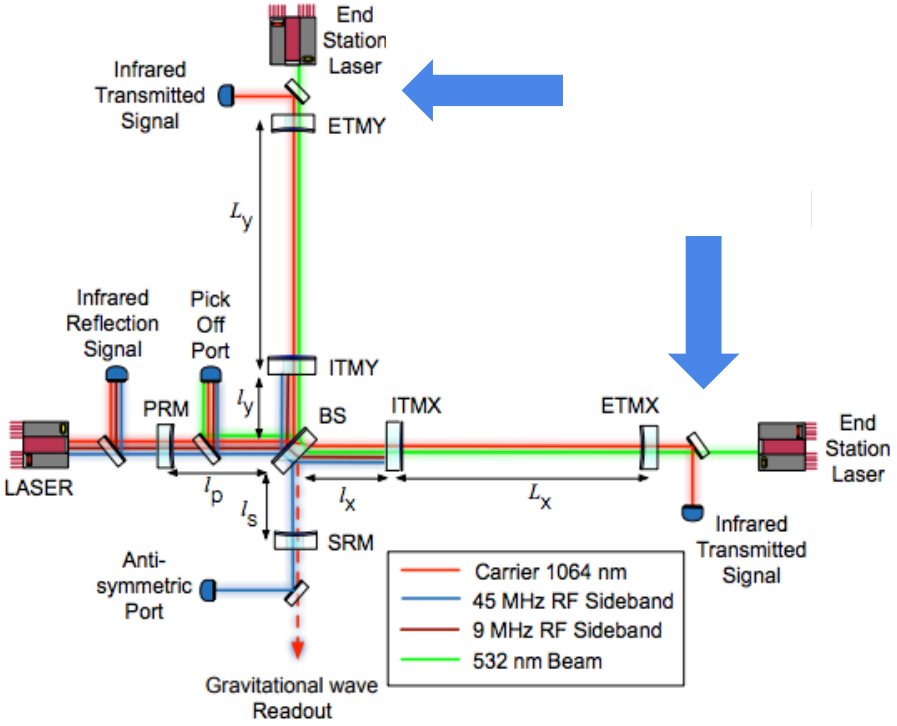
IV. Results

V. Future Work and Applications

Arm Length Stabilization (ALS)

ALS locks each arm individually using lasers mounted behind the test masses

Includes a polarization controller to correct for noise and polarization drift along the fiber optic cables

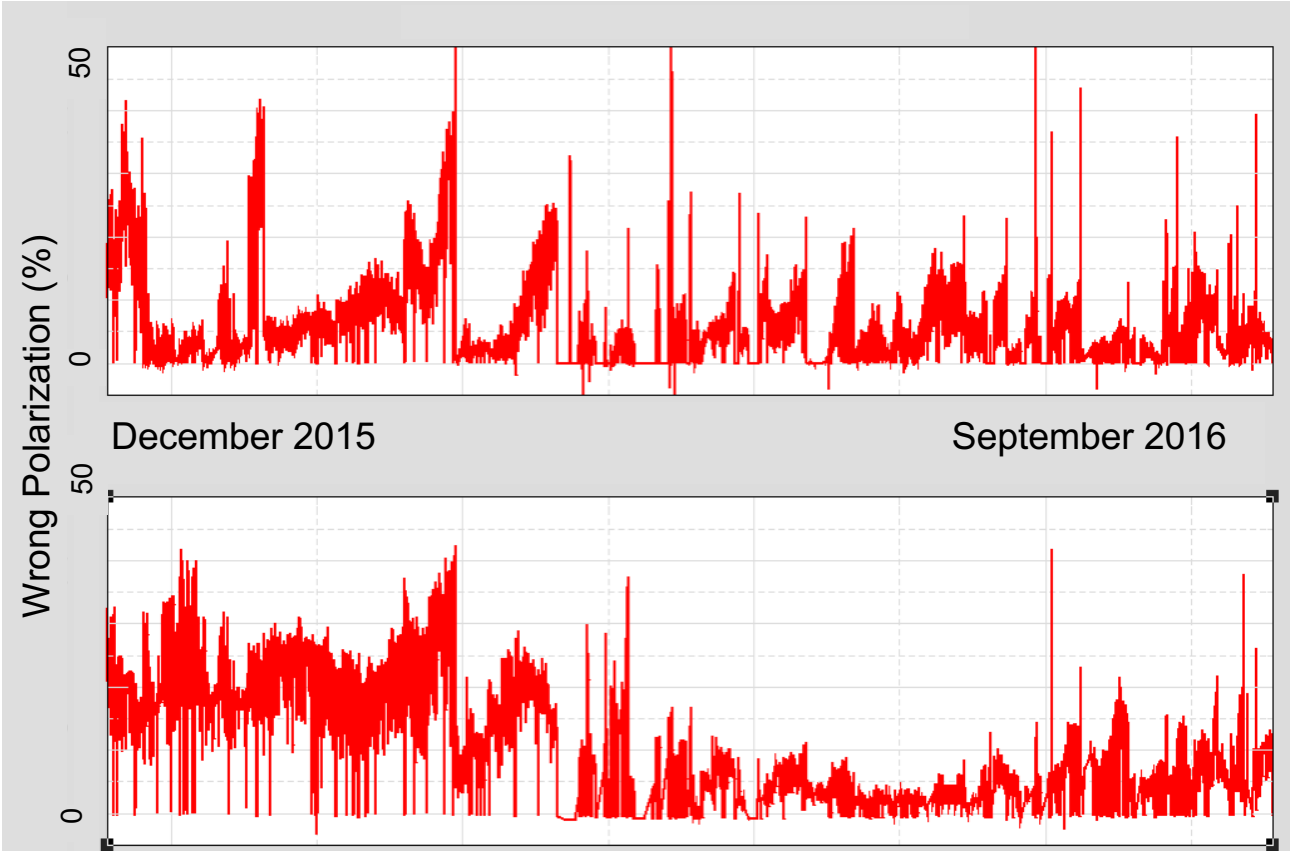


A. Staley et. al. Achieving Resonance in the Advanced LIGO Gravitational-Wave Interferometer. LIGO Document P1400105. 2014.

Polarization Drift

Y Arm

X Arm

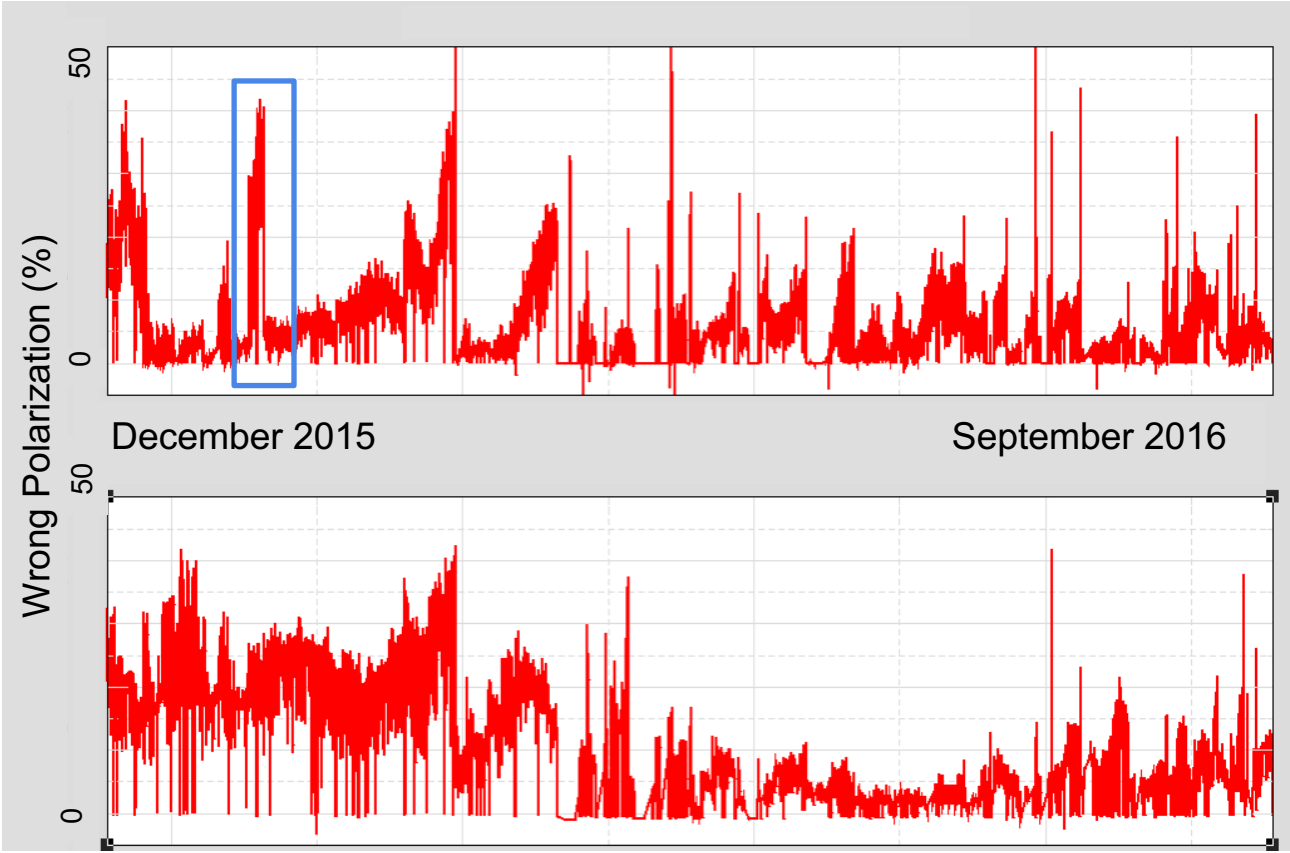


Trend of Polarization in ALS Fiber Transmission. Jeffrey Kissel, LHO Logbook, 11/18/2016

Polarization Drift

Y Arm

X Arm



Trend of Polarization in ALS Fiber Transmission. Jeffrey Kissel, LHO Logbook, 11/18/2016

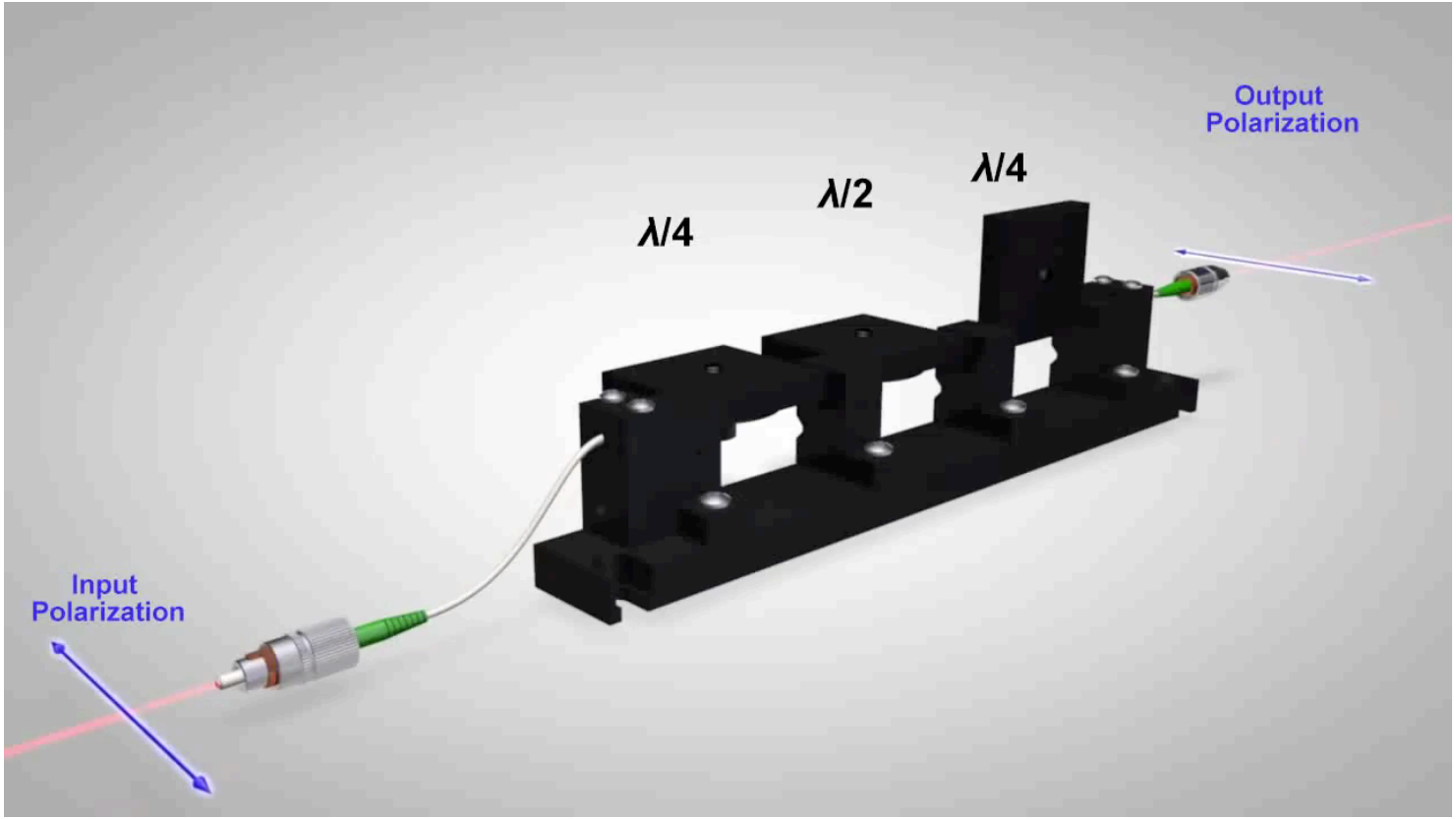
Motorized Polarization Controller

Located in the corner station, with dual channel controls (for altering X and Y arm)

Changes the state-of-polarization using stress induced birefringence

FiberControl. MPC-1 User and Programming Manual, Version 2-2. LIGO Document T1200496- v1. 2003.

Motorized Polarization Controller

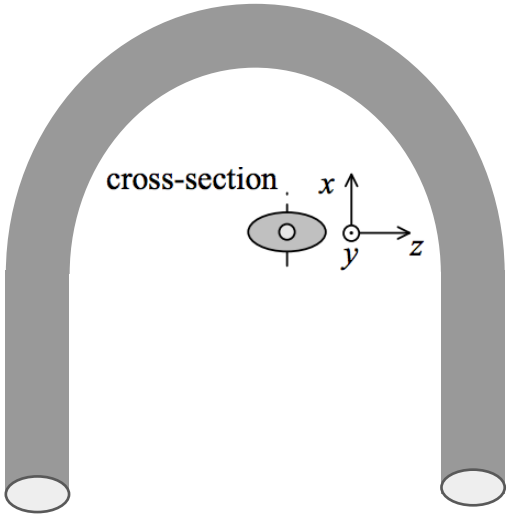


ThorLabs Fiber Paddle Polarization Controller. Overview of Manual Fiber Polarization Controller. 3/14/14

Stress Induced Birefringence

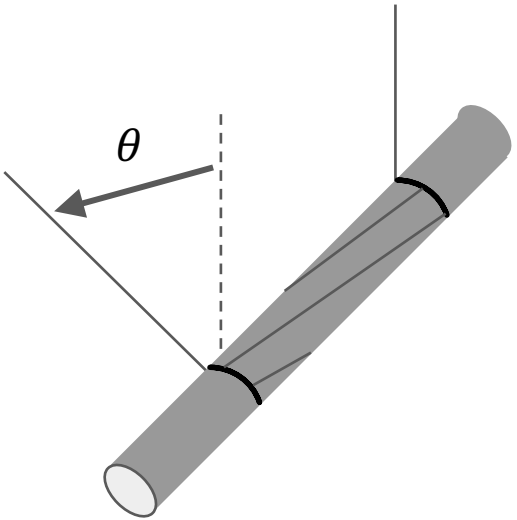
Bend

$$\Phi \propto \frac{Number\ of\ Turns \times Fiber\ Diameter^2}{Wavelength \times Coil\ Diameter}$$



Twist

$$\Phi \propto Angle\ Rotated$$



Polarization Adjustment

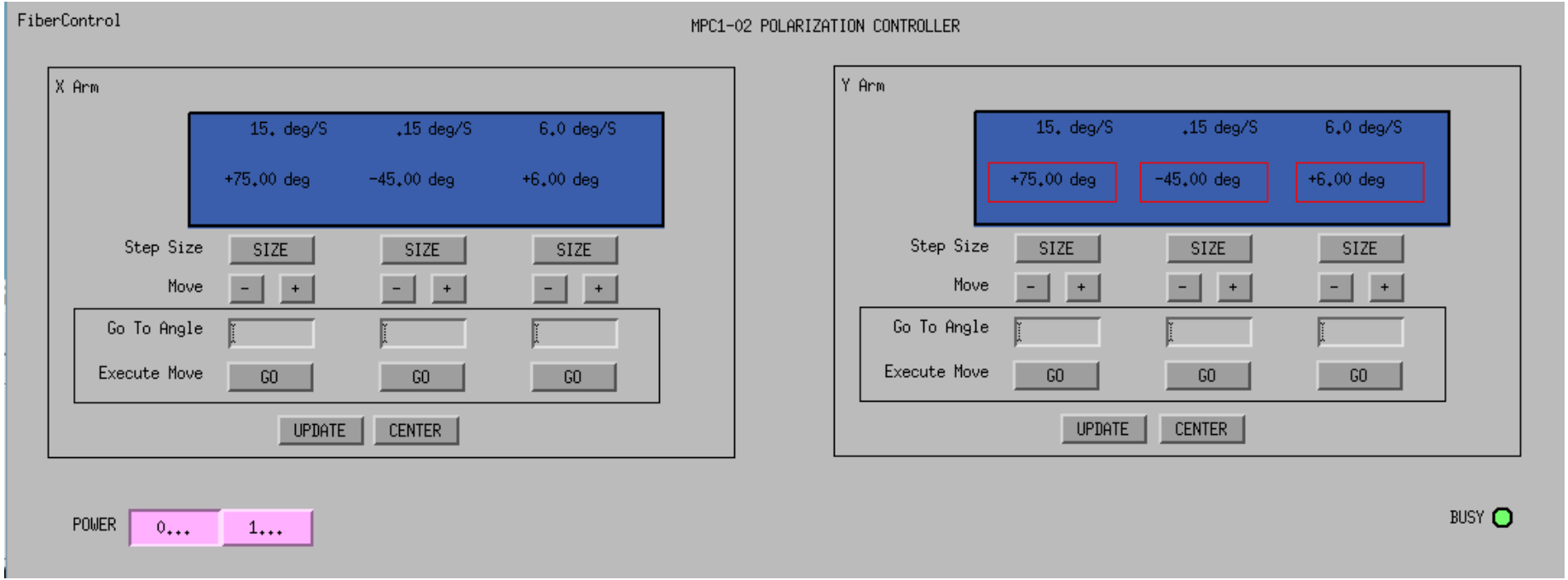
Complications make it difficult to calculate exact orientation needed

- Temperature fluctuations, imperfections in fibers, unintended mechanical stress, imperfections of ‘effective waveplates’

Instead, corrected using random walk to minimize percent rejected

- This has potential for automation, but first remote controls must be developed

Goal of Project



David Barker. *Model of User Interface*. LIGO Wiki, Motorized Polarizer Controller EPICS Remote Control. 2017.

Chain of Communication

- MEDM (user input)
- EPICS Database
- IOC
- TwinCAT PLC
- Motorized Polarization Controller

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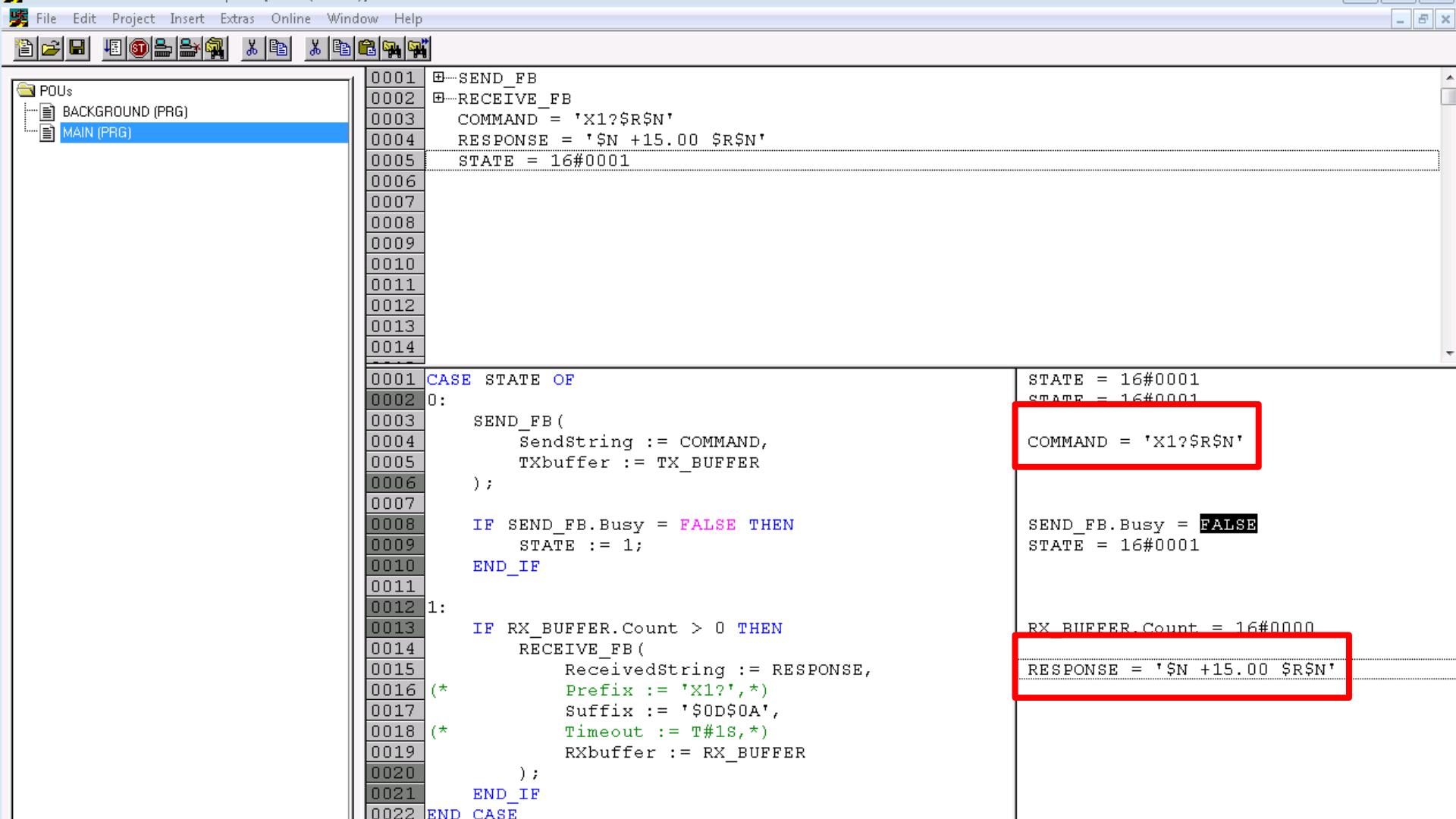
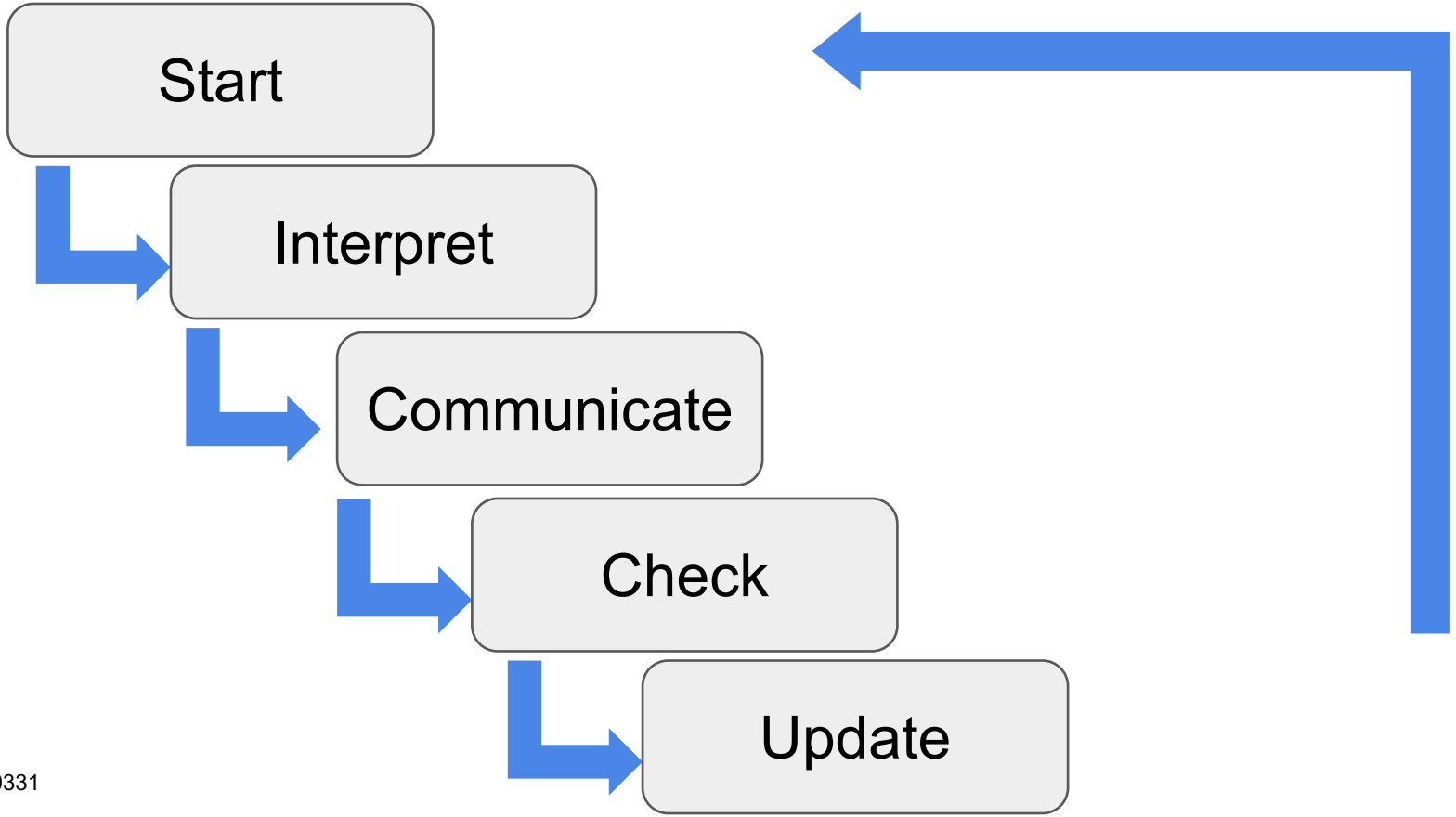
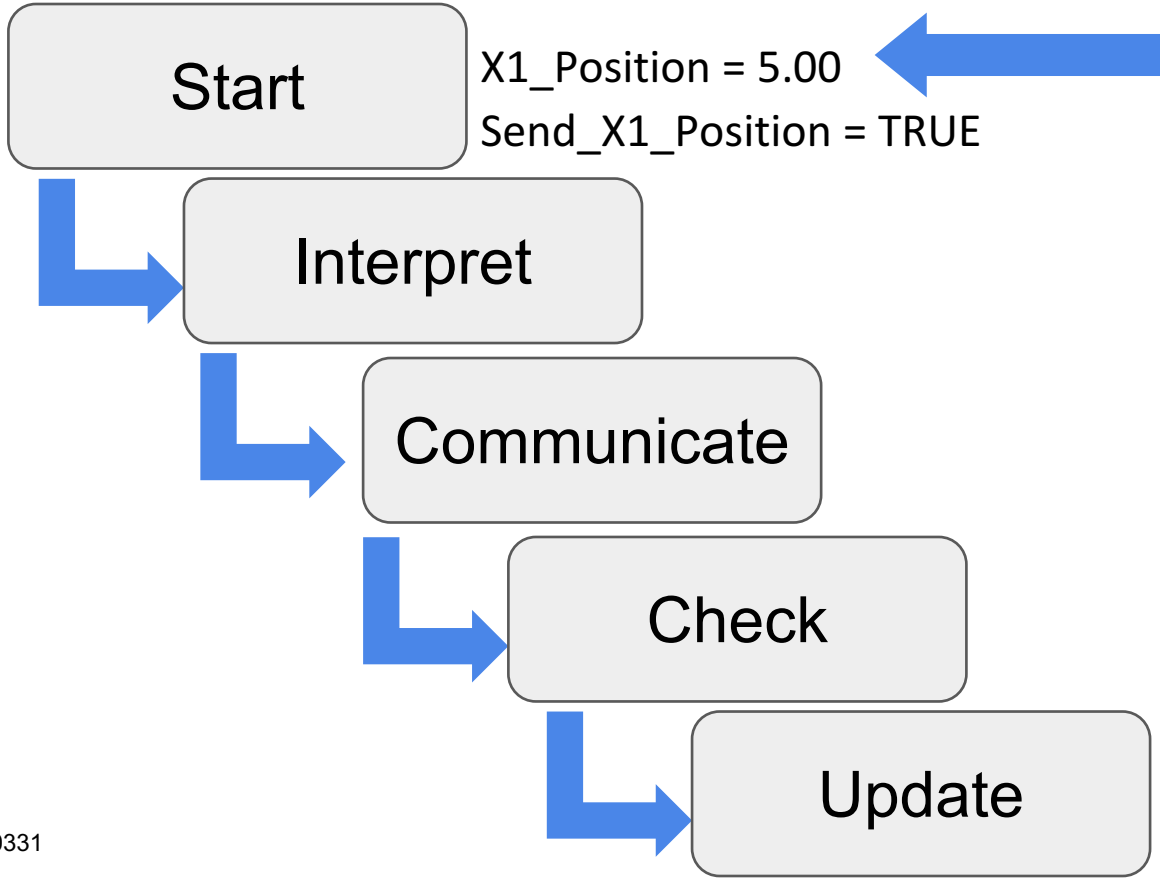

File Edit Project Insert Extras Online Window Help
POUs
BACKGROUND (PRG)
MAIN (PRG)
0001 SEND_FB
0002 RECEIVE_FB
0003 COMMAND = 'X1?RN'
0004 RESPONSE = '$N +15.00 RN'
0005 STATE = 16#0001
0001 CASE STATE OF
0002 0:
0003 SEND_FB(
0004 SendString := COMMAND,
0005 TXbuffer := TX_BUFFER
0006);
0008 IF SEND_FB.Busy = FALSE THEN
0009 STATE := 1;
0010 END_IF
0012 1:
0013 IF RX_BUFFER.Count > 0 THEN
0014 RECEIVE_FB(
0015 ReceivedString := RESPONSE,
0016 (* Prefix := 'X1?',*)
0017 Suffix := '$0D$0A',
0018 (* Timeout := T#1S,*)
0019 RXbuffer := RX_BUFFER
0020);
0021 END_IF
0022 END_CASE
STATE = 16#0001
COMMAND = 'X1?RN'
SEND_FB.Busy = FALSE
STATE = 16#0001
RESPONSE = '$N +15.00 RN'

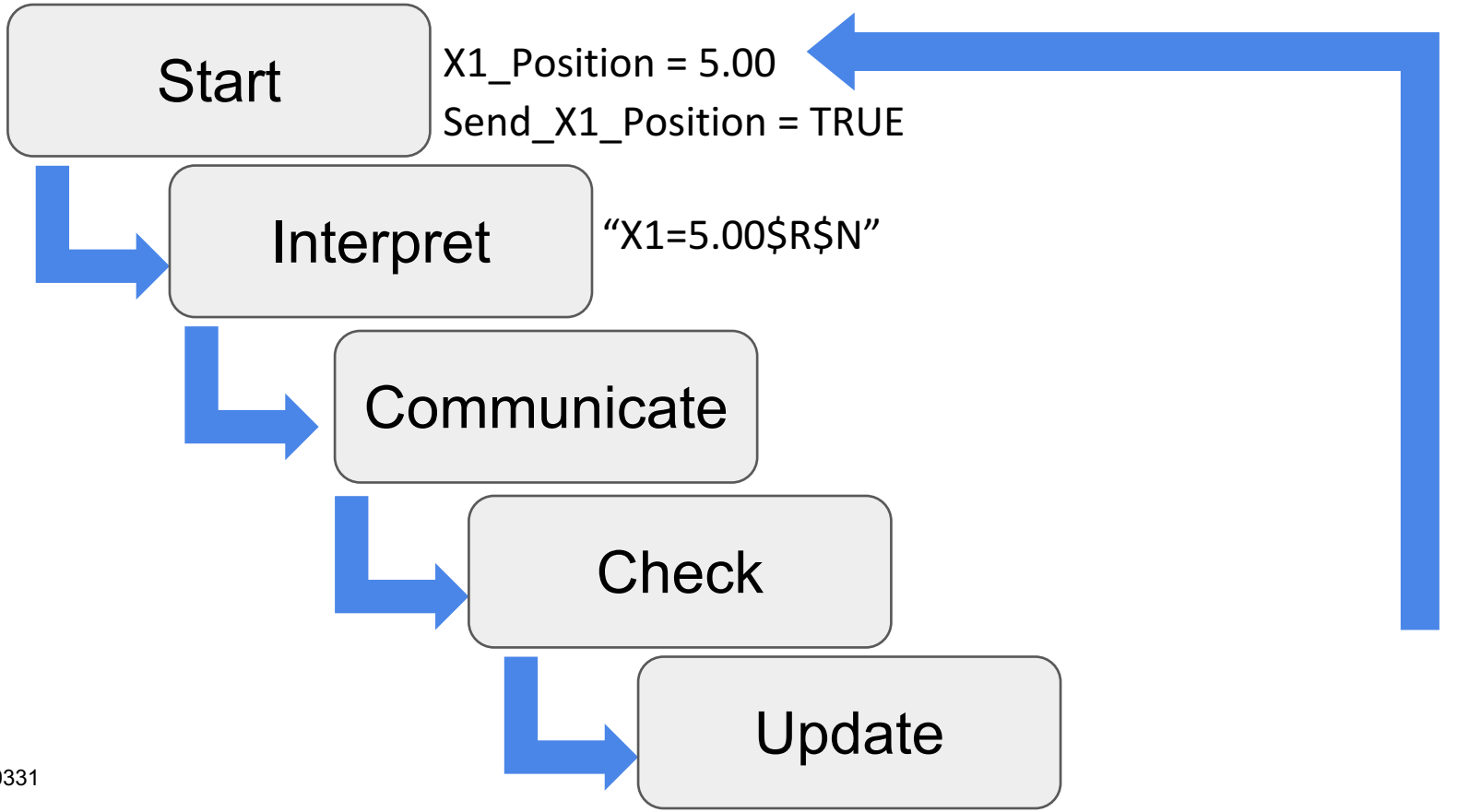
State Machine



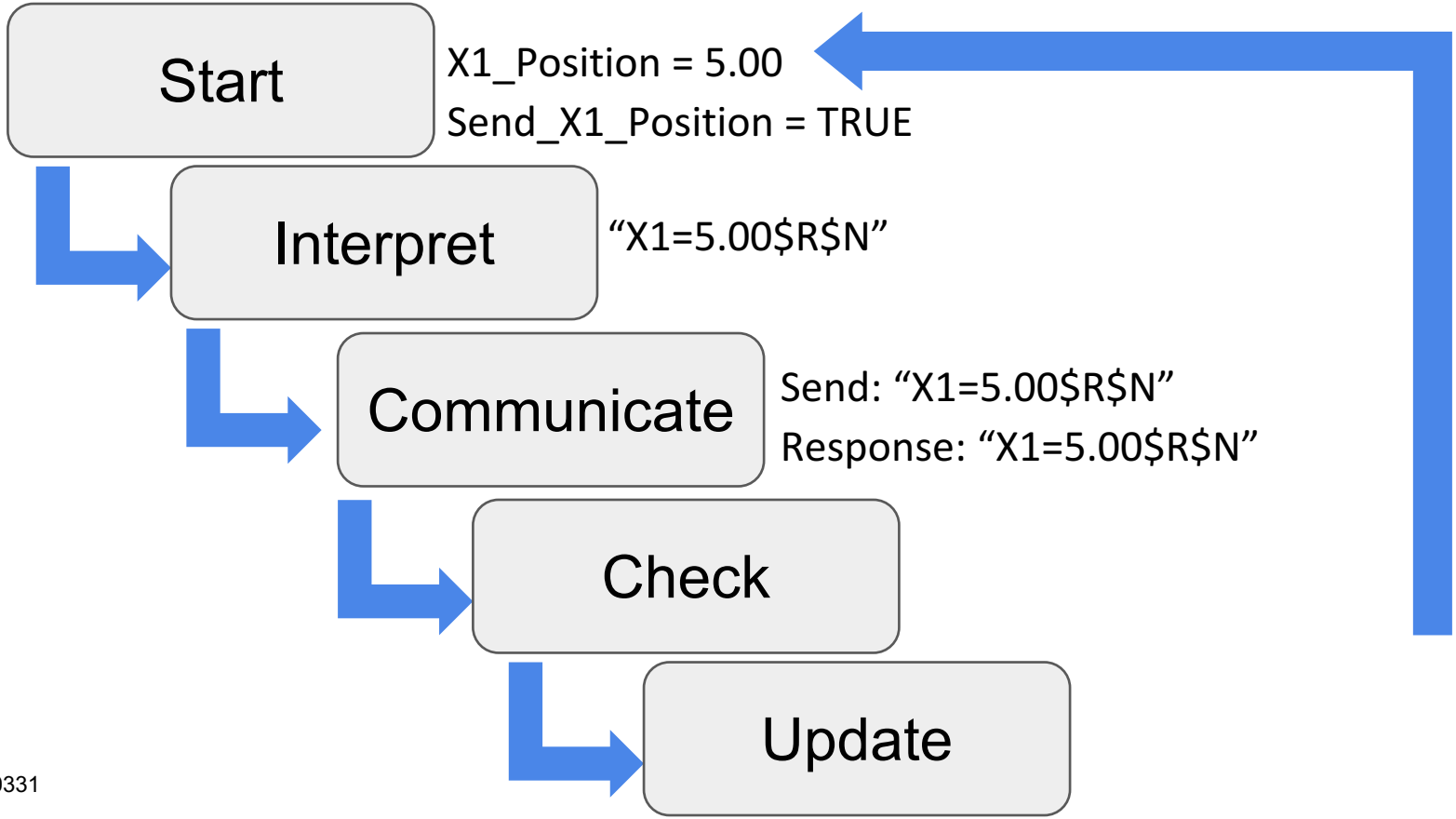
State Machine



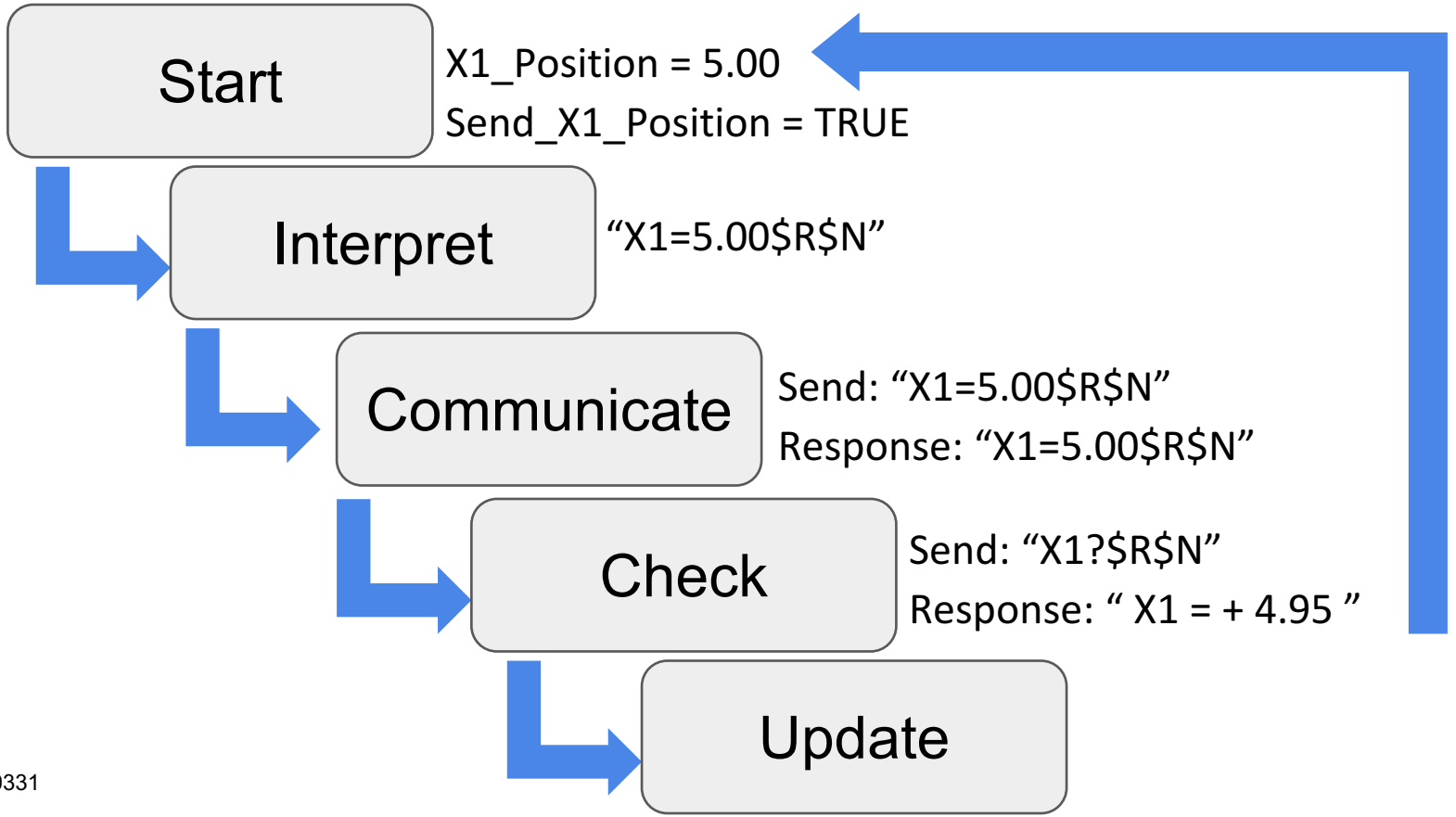
State Machine



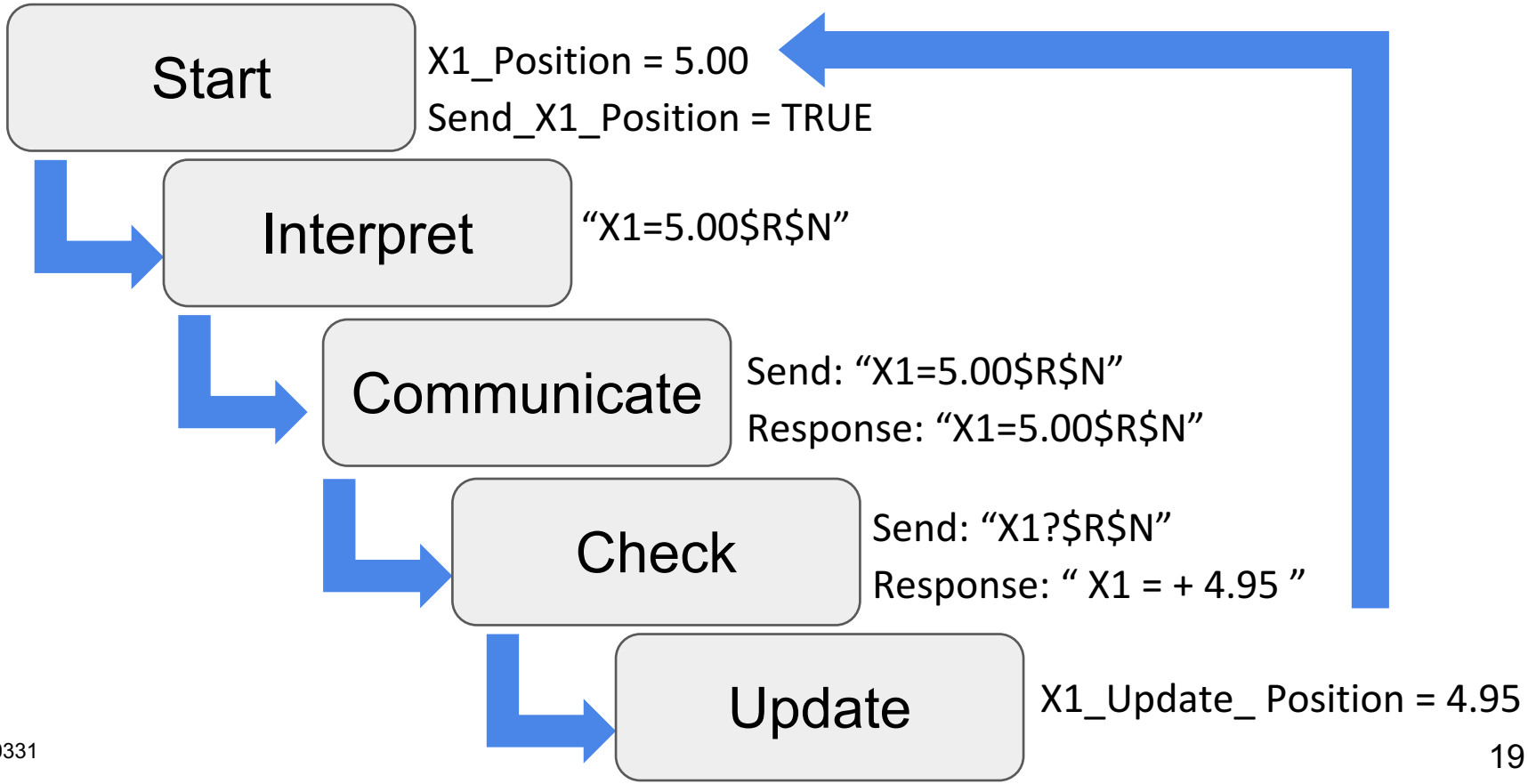
State Machine



State Machine



State Machine



Does it work?

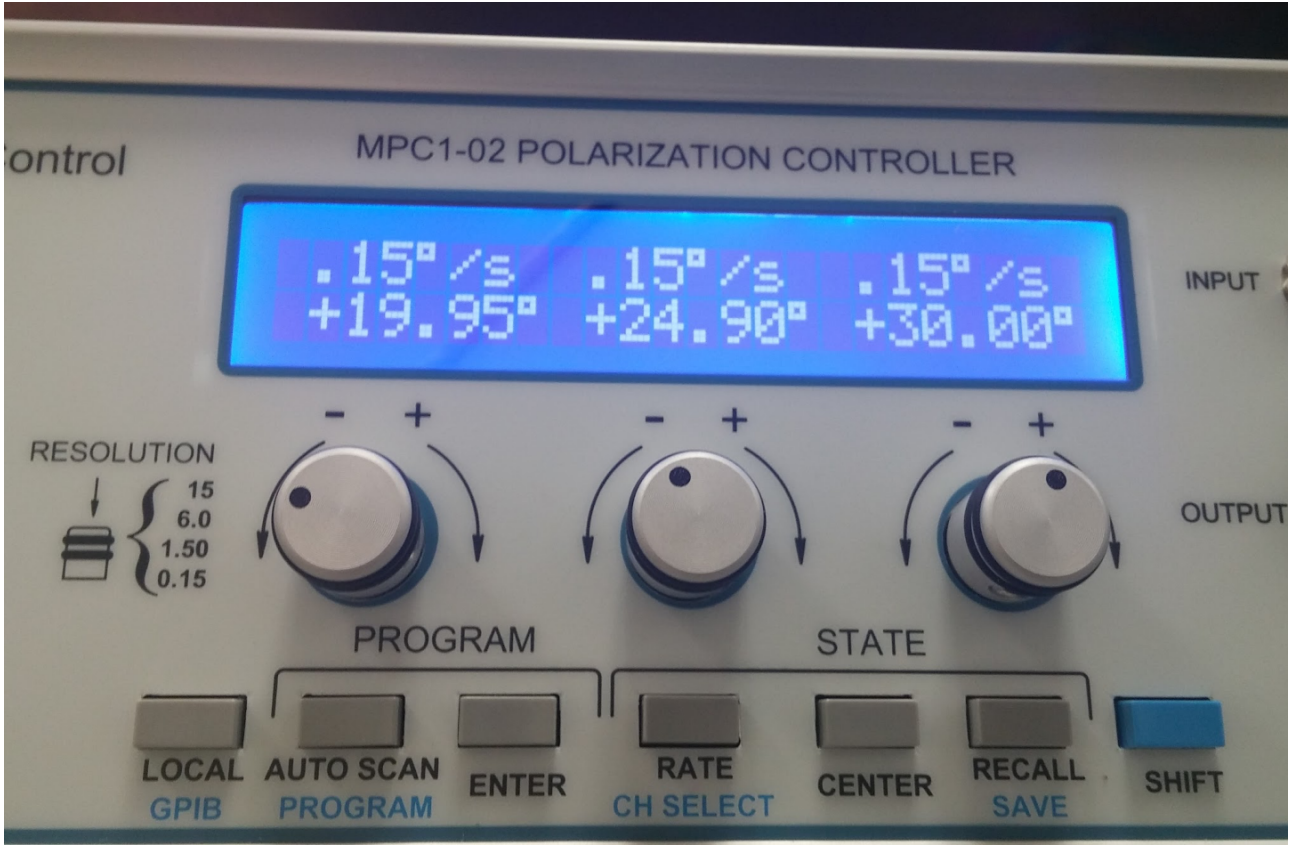
Global_Variables

```
0001  ⊞TX_BUFFER
0002  ⊞RX_BUFFER
0003     FIBER_POLARIZER_XARM_1 = '5.00'
0004     FIBER_POLARIZER_XARM_2 = '10.00'
0005     FIBER_POLARIZER_XARM_3 = '15.00'
0006     FIBER_POLARIZER_YARM_1 = '20.00'
0007     FIBER_POLARIZER_YARM_2 = '25.00'
0008     FIBER_POLARIZER_YARM_3 = '30.00'
0009     FIBER_POLARIZER_UPDATE_XARM_1 = 4.95
0010     FIBER_POLARIZER_UPDATE_XARM_2 = 9.9
0011     FIBER_POLARIZER_UPDATE_XARM_3 = 15
0012     FIBER_POLARIZER_UPDATE_YARM_1 = 19.95
0013     FIBER_POLARIZER_UPDATE_YARM_2 = 24.9
0014     FIBER_POLARIZER_UPDATE_YARM_3 = 30
0015  ⊞SystemInfo (%MB32768)
0016  ⊞SystemTaskInfoArr (%MB32832)
0017
0018
```

Does it work?


ontrol
MPC1-02 POLARIZATION CONTROLLER
.15°/s .15°/s .15°/s
+ 4.95° + 9.90° +15.00°
INPUT
OUTPU
RESOLUTION
15
6.0
1.50
0.15
PROGRAM
STATE
LOCAL
GPIB
AUTO SCAN
PROGRAM
ENTER
RATE
CH SELECT
CENTER
RECALL
SAVE
SHIFT

Does it work?


ontrol
MPC1-02 POLARIZATION CONTROLLER
.15°/s +19.95°
.15°/s +24.90°
.15°/s +30.00°
INPUT
OUTPUT
RESOLUTION
15
6.0
1.50
0.15
PROGRAM
STATE
LOCAL
GPIB
AUTO SCAN
PROGRAM
ENTER
RATE
CH SELECT
CENTER
RECALL
SAVE
SHIFT

Added Functionality

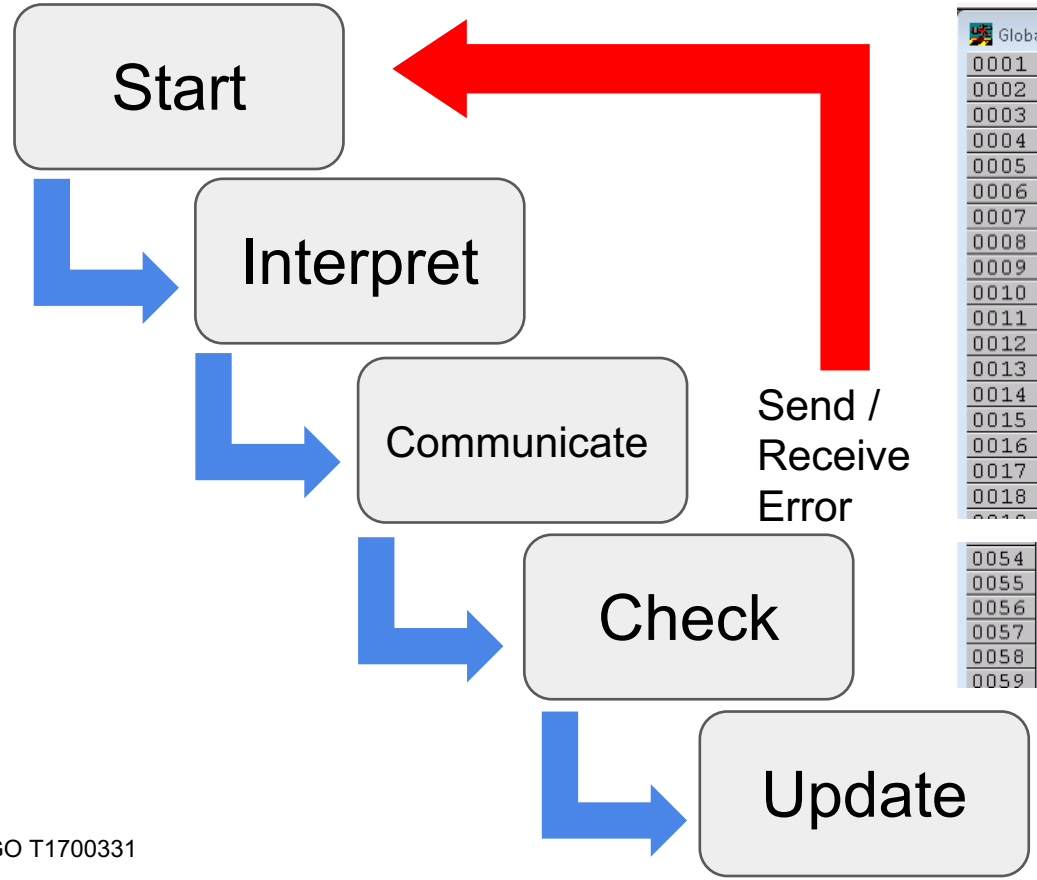
To mirror functionality of the physical MPC, we need:

- Scrolling
- Center
- Step size adjustment for coarse and fine adjustment
- Speed adjustment

Additional features are also needed specifically for remote controls:

- Rescan
- Busy monitor
- Remote power controls
- Robust error handling

Error Handling



Global_Variables

```
0001  TX_BUFFER
0002  RX_BUFFER
0003  SEND_FB
0004  RECEIVE_FB
0005    STATE = 0
0006    COMMUNICATION_STATE = RECEIVE
0007    UPDATE_STATE = 10
0008    PADDLE = X3
0009  SEND_RECEIVE_CASE
0010    COMMAND = ''
0011    RESPONSE = ''
0012    UPDATE_COMMAND = 'Z1?$R'
0013    UPDATE_RESPONSE = ''
0014    ERROR = FALSE
0015    ERROR_ID = RECEIVE_ERROR
0016    X_FIBER_POLARIZATION_1_POSITION_DEGREES_ERROR = FALSE
0017    X_FIBER_POLARIZATION_2_POSITION_DEGREES_ERROR = FALSE
0018    X_FIBER_POLARIZATION_3_POSITION_DEGREES_ERROR = TRUE
0054    Y_FIBER_POLARIZATION_2_MOVE_NEG_STEP = FALSE
0055    Y_FIBER_POLARIZATION_3_MOVE_NEG_STEP = FALSE
0056    C_FIBER_POLARIZATION_BUSY = TRUE
0057  SystemInfo (%MB32768)
0058  SystemTaskInfoArr (%MB32832)
0059
```

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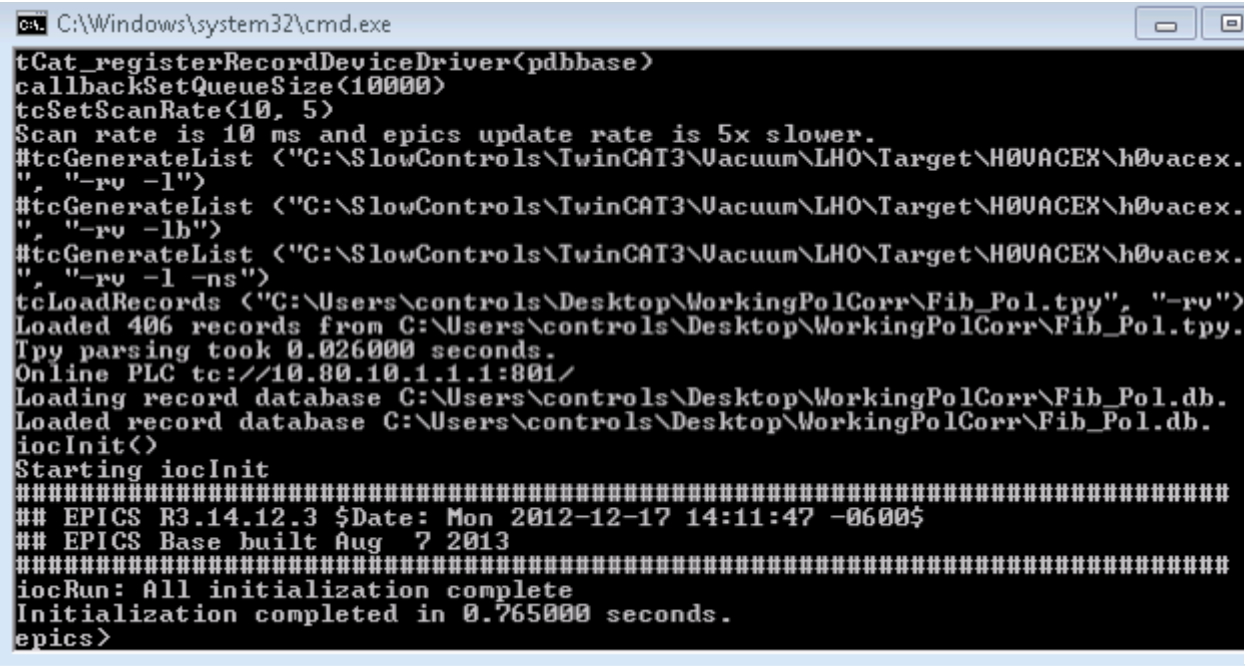
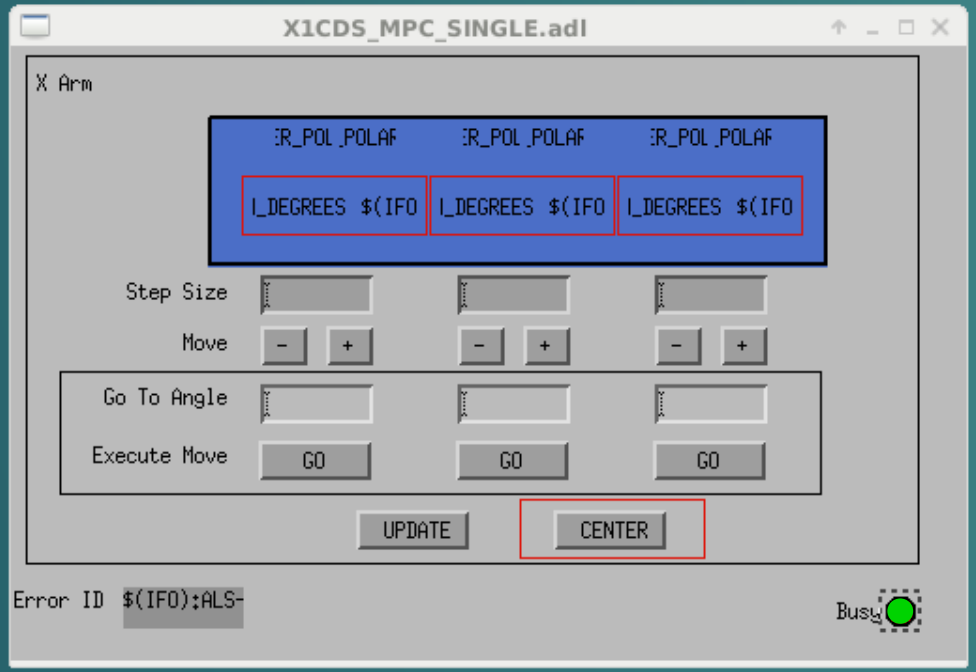
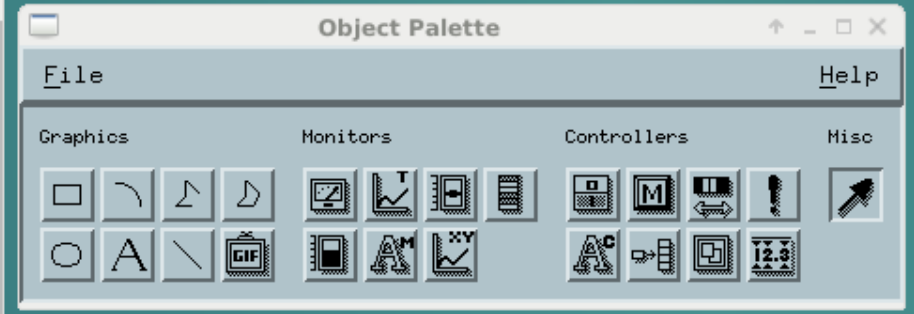
EPICS / IOC



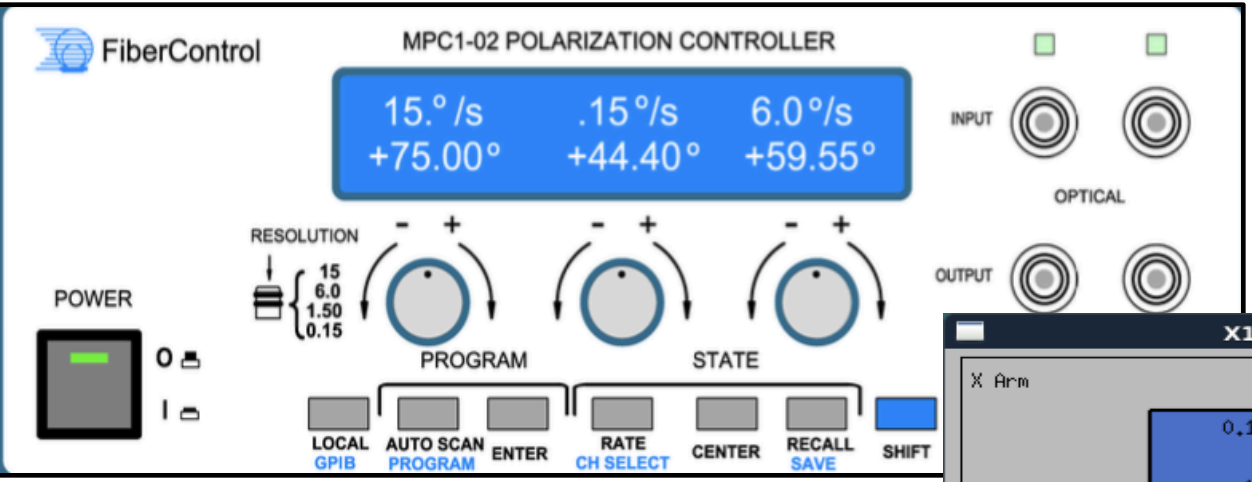

```
record(bo,"H1:ALS-X_FIBER_POLARIZATION_CENTER") {
      field(SCAN,"Passive")
      field(DTYP,"tcat")
      field(OUT,"@tc://10.80.10.1.1.1:801/16448/2202:1")
      field(TSE,"-2")
      field(PINI,"0")
}
record(bo,"H1:ALS-Y_FIBER_POLARIZATION_CENTER") {
      field(SCAN,"Passive")
      field(DTYP,"tcat")
      field(OUT,"@tc://10.80.10.1.1.1:801/16448/2203:1")
      field(TSE,"-2")
      field(PINI,"0")
}
record(bo,"H1:ALS-X_FIBER_POLARIZATION_1_GOTO_REQUEST_ANGLE") {
      field(SCAN,"Passive")
      field(DTYP,"tcat")
      field(OUT,"@tc://10.80.10.1.1.1:801/16448/2312:1")
      field(TSE,"-2")
      field(PINI,"0")
}
record(bo,"H1:ALS-X_FIBER_POLARIZATION_2_GOTO_REQUEST_ANGLE") {
      field(SCAN,"Passive")
      field(DTYP,"tcat")
      field(OUT,"@tc://10.80.10.1.1.1:801/16448/2313:1")
      field(TSE,"-2")
      field(PINI,"0")
}
record(bo,"H1:ALS-X_FIBER_POLARIZATION_3_GOTO_REQUEST_ANGLE") {
      field(SCAN,"Passive")
      field(DTYP,"tcat")
      field(OUT,"@tc://10.80.10.1.1.1:801/16448/2314:1")
      field(TSE,"-2")
      field(PINI,"0")
}
record(bo,"H1:ALS-Y_FIBER_POLARIZATION_1_GOTO_REQUEST_ANGLE") {
      field(SCAN,"Passive")
      field(DTYP,"tcat")
      field(OUT,"@tc://10.80.10.1.1.1:801/16448/2315:1")
```

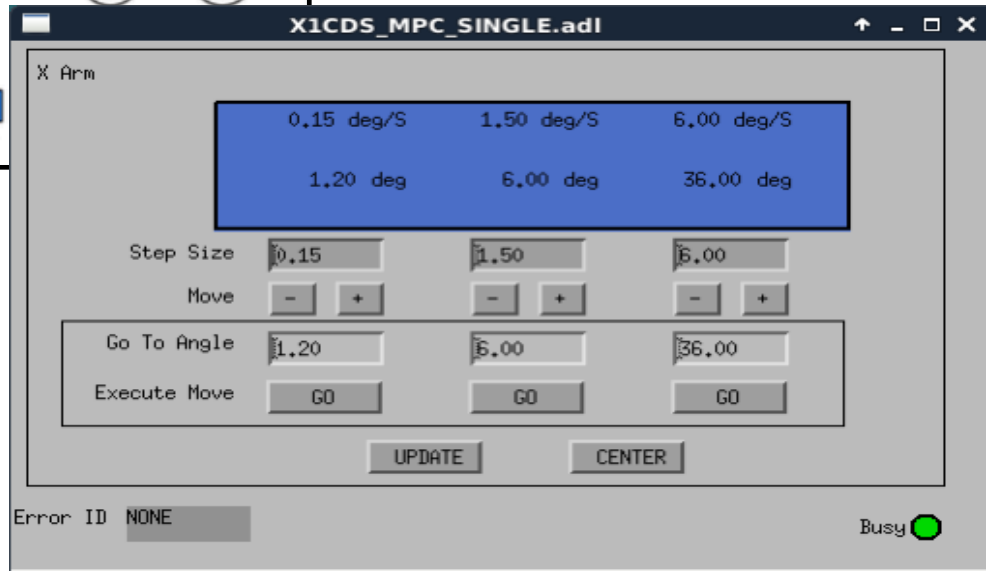
MEDM


X1CDS_MPC_SINGLE.adl
X Arm
:R_POL_POLAR
:R_POL_POLAR
:R_POL_POLAR
l_DEGREES $(IFO
l_DEGREES $(IFO
l_DEGREES $(IFO
Step Size
Move
Go To Angle
Execute Move
GO
GO
GO
UPDATE
CENTER
Error ID $(IFO):ALS-
Busy


Object Palette
File
Help
Graphics
Monitors
Controllers
Misc

MEDM





FiberControl. *MPC-1 User and Programming Manual, Version 2-2.* LIGO Document T1200496-v1. 2003.

Complete MEDM

Future Applications and Work

Immediate future work:

Adding power button to MEDM screen and power control to box

Near future applications:

Automation of search for paddle position that minimizes light rejection

Possible investigations:

Discrepancy between speed of paddles and busy monitor

Exact effective retardance of each paddle for given wavelength

Conclusion

Basic communication and controls established

User interface developed for simple and intuitive operation of remote controls

Allows for DAQ storage of numeric channels

Opens up the potential not only for digital controls, but also automation of polarization correction

Acknowledgments

Daniel Sigg

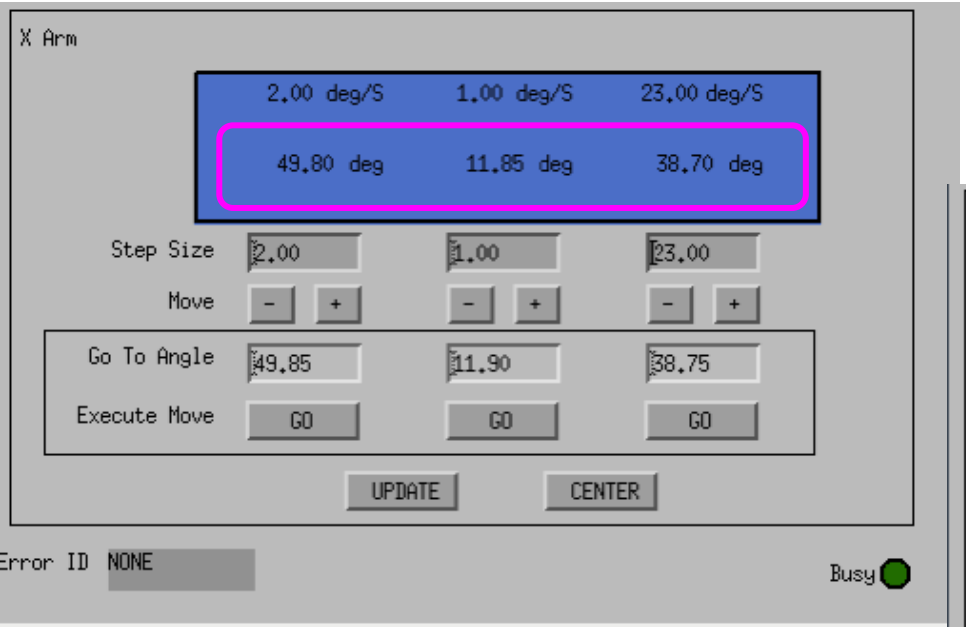
Dave Barker

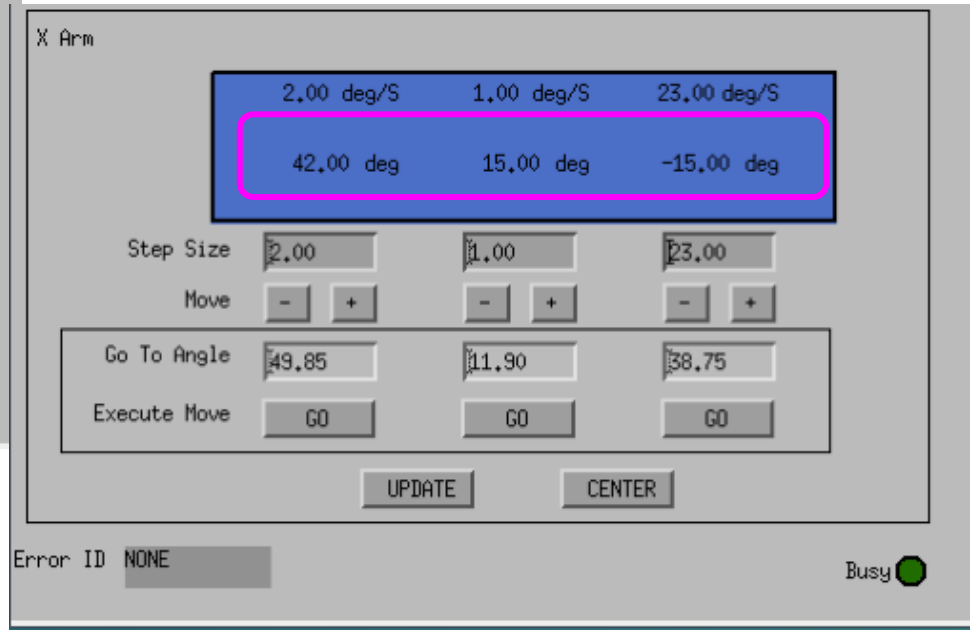
Patrick Thomas

Richard McCarthy

Support provided by Caltech SURF, funded by the NSF

Update Command





Motorized Polarization Controller