IG2 User Manual

PYRAMID TECHNICAL CONSULTANTS, INC.

C. PENDLETON

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1. GENERAL INFORMATION

1.1 Document Approval

This document has been reviewed and approved by the following individuals:

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1.2 Revision History

Version	Date	Author(s)	Comments
1.1.0	October 3, 2013	C. Pendleton	Added “noscale” wires to BPM
1.2.0	October 16, 2013	C. Pendleton	Added supported device types (H10, F460, B10, N2400, I128)
1.3.0	November 7, 2013	C. Pendleton	Added F460 I/O
1.4.0	November 21, 2013	C. Pendleton	Added memblock type
1.5.0	December 30, 2013	C. Pendleton	Added I128 I/O
2.0.0	January 7, 2014	C. Pendleton	Added F460 I/O, I128 bug fixes, renamed document
2.0.1	February 16, 2014	C. Pendleton	I128 bug fixes, added I/O
			Added C400 as a supported device
			Added asciiclient and kollmorgen devices
			Added C400 I/O
2.1.0	March 13, 2014	C. Pendleton	Added Keithley 238 GPIB support
2.2.0	April 8, 2014	C. Pendleton	Added IC101 support

			Added IC101 I/O
2.3.0	September 16, 2014	C. Pendleton / J. Iken	Modified kollmorgen device
			Modified F460 device
			Added H20 device
2.4.0	September 30, 2014	C. Pendleton	Added channel buffering
2.4.1	October 9, 2014	J. Iken	Added F100
			Added H20 I/O
2.4.2	October 29, 2014	J. Iken	Added I128 I/O
2.4.4	April 20, 2015	J. Iken	Added I/0
2.4.5	May 29, 2015	J. Iken	Added IC101 I/O
2.4.6	June 25, 2015	J. Iken	Added H20 I/O
2.4.7	July 9, 2015	J. Iken	Kollmorgen Modbus
2.4.8	August 6, 2015	J. Iken	Added I128 I/O Added Kollmorgen I/O
2.4.9	August 31, 2015	J. Iken	Fixed Ionchamber bug
2.5.0	September 16, 2015	J. Iken	Added I200 Support
2.5.1	September 29, 2015	J. Iken	Added I200 Buffered Wires Added F460 I/O
2.5.1	October 7, 2015	J. Iken	Added I128 I/O
2.5.2	October 20, 2015	J. Iken	Various bug fixes (I128, Kollmorgen, EPICS)
2.5.3	October 28, 2015	J. Iken	monitorOnlyChange paramter

1.3 Reference documents

Document	Rev	Author(s)	Comments

2. CONTENTS

3. WHAT IS EPICS?

From the EPICS website (http://www.aps.anl.gov/epics/index.php):

“EPICS is a set of software tools and applications which provide a software infrastructure for use in building distributed control systems to operate devices such as Particle Accelerators, Large Experiments and major Telescopes. Such distributed control systems typically comprise tens or even hundreds of computers, networked together to allow communication between them and to provide control and feedback of the various parts of the device from a central control room, or even remotely over the internet.

EPICS uses Client/Server and Publish/Subscribe techniques to communicate between the various computers. Most servers (called Input/Output Controllers or IOCs) perform real-world I/O and local control tasks, and publish this information to clients using the Channel Access (CA) network protocol. CA is specially designed for the kind of high bandwidth, soft real-time networking applications that EPICS is used for, and is one reason why it can be used to build a control system comprising hundreds of computers.”

4. HOW DOES IG2 USE EPICS?

IG2 includes an optional Channel Access Server (CAS), or Portable Server, that implements EPICS Channel Access Protocol. This allows any EPICS client software to readback and control IG2 I/O points using EPICS Process Variables (PVs).

IG2 has a database of named I/O points, called channels, listed in its configuration file (default: system.xml). Each of these channels has an associated type and direction. These channels map one-to-one to EPICS PVs made available by IG2. This list of channels represents the full list of EPICS PVs available.

This hardware configuration file contains a section for virtual devices that allows the EPICS CAS to be enabled in IG2. To enable the EPICS CAS in IG2, add the following <epicscas> node to the <interpreter> section of the file.

```
### system.xml
<interpreter>
  <devices>
    <epicscas type=”epicscas” name=”epics_server” />
  </devices>
</interpreter>
###
```

5. WHAT EPICS SOFTWARE CAN BE USED WITH IG2?

Almost any EPICS software tool can be used with IG2. There is a vast selection of canned tools and programming APIs available. Many of them can be found on the EPICS website: http://www.aps.anl.gov/epics/extensions/index.php. There is support for C/C++, Java, LabView, Matlab, Perl, Python, C#, PHP, and other languages. There are canned tools for backup/restore, archiving, plotting, and monitoring.

Any EPICS client that need to communicate with IG2 must be in the same network broadcast domain as IG2.

6. IG2 USAGE AND STARTUP

IG2 is a console application that takes one command line argument for the path of the xml configuration file. Example:

ig2-2.0.2 c:\config\mysystem.xml

The configuration file path argument is optional. IG2 will use “system.xml” by default, located in the local application directory.

7. IG2 CONFIGURATION AND CHANNELS

The system.xml file contains a listing of the hardware configuration that IG2 will manage. This configuration is user-specific. IG2 offers a set of device types that can be controlled. A set of I/O points, called wires, is available within an instance of each of these device types. Users can define an arbitrary number of channels within the device instance which map to a specified wire to provide control and readback.

```
### system.xml
<board type="M10" name="XQ7_ctrl" address="7">
  <channels>
        <channel name="c_XQ7_current_ctrl" wire="analog_out_1" limitLow="-10" limitHigh="10" />
        <channel name="r_XQ7_current_ctrl" wire="analog_in_1"  scaleB=”2” scaleC=”1” />
        <channel name="r_XQ7_thermalok" wire="digital_in_1" />
        <channel name="c_XQ7_remote" wire="digital_out_2" />
  </channels>
</board>
###
```

The above example shows an M10. The main node is a <board> with attributes that specifies it as an M10 named XQ7_ctrl at address 7. Channels names are arbitrary, but must be unique. There are 4 channels defined, and each has a specified M10 wire. Channel “r_XQ7_current_ctrl” is connected to M10 wire “analog_in_1”. This wire correspond to the physical M10 ADC channel 1. The data type of the wire is embedded in the first part of the wire name. The direction is also embedded in the wire name, after the data type. A table of supported data types and directions is listed below. The “xxx” part of the wire name is specific to the device that the wire is assigned to.

Wire name	Data Type	User Access
analog_in_xxx	Double precision float (64 bit)	Read only
analog_out_xxx	Double precision float (64 bit)	Read/Write
int_in_xxx	Integer (32 bit)	Read only
int_out_xxx	Integer (32 bit)	Read/Write
digital_in_xxx	Integer (32 bit) 0=false, non-zero=true	Read
digital_out_xxx	Integer (32 bit) 0=false, non-zero=true	Read/Write
variant_in_xxx	Array of Double precision floats (64 bit)	Read
variant_out_xxx	Array of Double precision floats (64 bit)	Read/Write
analog[n]_in_xxx	Array of Double precision floats (64 bit) of length n	Read
analog[n]_out_xxx	Array of Double precision floats (64 bit) of length n	Read/Write
string_in_xxx **(not supported with IG2/EPICS)**	Null-terminated string	Read
string_out_xxx **(not supported with IG2/EPICS)**	Null-terminated string	Read/Write

Table 1 - Supported Data Types and User Access

7.1.1 Channel Scaling

Channels have optional scale factors to convert between user units and device units. These scale factors apply only to analog data types. This can be seen in the above M10 channel example. The channel “r_XQ7_current_ctrl” specifies 2 scale factor attributes – “scaleB” and “scaleC”. These correspond to a linear scaling with the following relationship.

<!-- y = Bx + C, where y=user units, and x=device units -->

These scale factors are optional. If not specified in the channel node, scaleB=1 and scaleC=0.

7.1.2 Channel Limits

Channels have optional upper and lower limits. These limits apply only to analog output types, and are in user units. This can be seen in the above M10 channel example. The channel “c_XQ7_current_ctrl” specifies 2 limit attributes – “limitLow” and “limitHigh”. This channel cannot be set to a value lower than limitLow or higher than limitHigh. These limits are set independently of the physical limits on the device. For a description of each physical Pyramid device, see the device data sheet and manual at http://ptcusa.com/products.html.

7.1.3 Channel Buffering

EPICS buffering is limited, and high-rate updates due to the processing of burst device data can cause data loss. IG2 features additional buffering controls designed to control flow of this type of data into the EPICS layer. The full design and advanced options are shown in Appendix 1.

To enable sample buffering on an individual channel, modify the channel node in the XML configuration file to contain the optional aMax parameter:

<channel name=”bufferedchn” wire=”analog_in_1” **aMax=”50”** />

Set aMax to the maximum size of the device’s buffered acquisition to ensure that data is not lost. It can likely be set lower than this, as the throughput of an individual channel depends on several factors including client performance and overall number of channels in the system. aMax is an optional parameter and defaults to 0 (unbuffered).

7.1.4 Monitor Only Change

An EPICS monitor event is called on the client when a channel is updated. This can be triggered at a very high rate, even on channels that do not have constantly changing values. To disable the event unless the new value is different, modify the channel node in the XML configuration file to contain the optional monitorOnlyChange parameter:

<channel name=”digitalchn” wire=”digital_in_1” **monitorOnlyChange=”true”** />

Set monitorOnlyChange to true if you only want to see a monitor event when the value changes. The default is set to false. This can only be used on digital, integer, or analog channels.

8. SUPPORTED DEVICE TYPES AND WIRES

The system.xml hardware configuration is separated into 2 main sections, or nodes. The first is <loopcontrollers>. This section contains a complete listing of standard Pyramid hardware devices in the system. The other section is called <interpreter>. This section contains a listing of custom hardware and virtual devices. The tables below list supported device types and their associated i/o (wires).

9. PYRAMID DEVICES

(<loopcontroller> section)

Each device in this section is supported in some device hierarchy. Loop controller devices can be directly communicated with over Ethernet. Fiber slave devices must be paired with a compatible Pyramid loop controller. Pyramid loop controllers can have one of two communication protocols.

G1 loop controllers = A500 (Does not support simultaneous communication with IG2 and Diagnostic)

G2 loop controllers = A560, A360, F460, I128

9.1 M10

<board type="M10" … > (Fiber slave device, G1, G2 loopcontroller support)

Wire	Description
digital_out_initiate	Initiate command (1 = Initiate, 0 = Abort)
int_out_stop_count	If < 1, no stop
analog_in_1	ADC channel 1 (volts)
analog_in_2	ADC channel 2 (volts)
analog_out_1	DAC channel 1 (volts)
analog_out_2	DAC channel 2 (volts)
digital_in_1	TTL digital input channel 1
digital_in_2	TTL digital input channel 2
digital_in_3	TTL digital input channel 3
digital_in_4	TTL digital input channel 4
digital_out_1	TTL digital output channel 1
digital_out_2	TTL digital output channel 2
digital_out_3	TTL digital output channel 3
digital_out_4	TTL digital output channel 4

9.2 M40

<board type="M40" … > (Fiber slave device, G1, G2 loopcontroller support)

Wire	Description
digital_out_initiate	Initiate command

	(1 = Initiate, 0 = Abort)
int_out_stop_count	If < 1, no stop
analog_in_1	ADC channel 1 (volts)
analog_in_2	ADC channel 2 (volts)
analog_in_3	ADC channel 3 (volts)
analog_in_4	ADC channel 4 (volts)
analog_in_5	ADC channel 5 (volts)
analog_in_6	ADC channel 6 (volts)
analog_in_7	ADC channel 7 (volts)
analog_in_8	ADC channel 8 (volts)
analog_out_1	DAC channel 1 (volts)
analog_out_2	DAC channel 2 (volts)
analog_out_3	DAC channel 3 (volts)
analog_out_4	DAC channel 4 (volts)
analog_out_5	DAC channel 5 (volts)
analog_out_6	DAC channel 6 (volts)
analog_out_7	DAC channel 7 (volts)
analog_out_8	DAC channel 8 (volts)
digital_in_1	TTL digital input channel 1
digital_in_2	TTL digital input channel 2
digital_in_3	TTL digital input channel 3
digital_in_4	TTL digital input channel 4
digital_in_5	TTL digital input channel 5
digital_in_6	TTL digital input channel 6
digital_in_7	TTL digital input channel 7
digital_in_8	TTL digital input channel 8
digital_out_1	TTL digital output channel 1
digital_out_2	TTL digital output channel 2
digital_out_3	TTL digital output channel 3

digital_out_4	TTL digital output channel 4
digital_out_5	TTL digital output channel 5
digital_out_6	TTL digital output channel 6
digital_out_7	TTL digital output channel 7
digital_out_8	TTL digital output channel 8

9.3 I200

<board type="I200" name="TODO" ip="TODO" port="100" updatePort="55701" retry="2" timeout="500" updateRate="3">
(Fiber slave device, G1, G2 loopcontroller support)

Wire	Description
digital_out_initiate	Initiate/abort acquisition control 0: Abort 1: Initiate
analog[5]_in_data	5-element array of channel data (A) [0] Trigger Count [1] Channel A current (A) [2] Channel B current (A) [3] Channel A charge (C) [4] Channel B charge (C) -10000 = overrange
analog[5]_in_buffered_data	5-element array of buffered channel data. This has same structure as **analog[5]_in_data**. This wire is used when trigger points is non-infinite. Use aMax in xml to ensure all samples are collected.
int_out_trigger_source	Set trigger source (1-4) 1: Internal 2: External Start 3: External Start Stop 4: External Start Hold
int_out_trigger_connector	Set trigger connector (1-2) 1: BNC 2: Optical
int_out_trigger_points	Set trigger points

	-1: Infinite Any other positive value starts buffered mode, which uses **analog[5]_in_buffered_data**
int_in_trigger_count	Trigger Count Is updated in both buffered and non-buffered mode
int_out_capacitor	Capacitor configuration control (0-1) 0: 10pF 1: 1000pF
analog_out_integration_period	Set integration period (sec)
int_out_subsamples	Set # of subsamples (1-255)
analog_out_range	Set range (A)
int_out_hv_external_bias	Set high voltage (V)
analog_in_hv_external_bias	Read high voltage (V)

9.4 I3200

<board type="I3200" … > (Fiber slave device, G1, G2 loopcontroller support)

Wire	Description
variant_in_current	32-element array of channel data (A)
digital_in_measuring	I3200 measuring mode indicator
analog_in_bias	High voltage readback (volts)
digital_in_actuator_limitA	Actuator limit A readback
digital_in_actuator_limitB	Actuator limit B readback
digital_out_actuator	Actuator position control
analog_out_bias	High voltage control (volts)
analog_out_period	I3200 integration time configuration control
int_out_capacitor	I3200 capacitor configuration control (0 or 1)
digital_out_initiate	I3200 initiate acquisition control

9.5 F3200E

<board type="F3200E" … > (G2 loopcontroller support)

Wire	Description
variant_in_data	32 elements of channel data (A) 1 element of sample info A (bit convert to int) 1 element of sample info B (bit convert to int) 4 elements of ADC 3 elements of DAC command 1 overrange bitmask
analog_out_adc_1 (not yet added)	ADC out channel 1 (V)
analog_out_adc_2 (not yet added)	ADC out channel 2 (V)
analog_out_adc_3 (not yet added)	ADC out channel 3 (V)
analog_in_adc_1 (not yet added)	ADC in channel 1 (V)
analog_in_adc_2 (not yet added)	ADC in channel 2 (V)
analog_in_adc_3 (not yet added)	ADC in channel 3 (V)
analog_in_adc_4 (not yet added)	ADC in channel 4 (V)
digital_in_1 (not yet added)	TTL digital input channel 1
digital_in_2 (not yet added)	TTL digital input channel 2
digital_in_3 (not yet added)	TTL digital input channel 3
digital_in_4 (not yet added)	TTL digital input channel 4
digital_out_1 (not yet added)	TTL digital output channel 1
digital_out_2 (not yet added)	TTL digital output channel 2
digital_out_3 (not yet added)	TTL digital output channel 3
digital_out_4 (not yet added)	TTL digital output channel 4
digital_out_initiate	Initiate measurement (1=initiate, 0 =abort)
variant_in_range	16 elements of range (F3200_10uA Range = 0 F3200_100uA Range = 1 F3200_1mA Range = 2

	F3200_100mA Range = 3)
variant_out_range_set	1 element of bank (1-16) If bank == -1, all ranges are set 1 element of range (0-3) (F3200_10uA Range = 0 F3200_100uA Range = 1 F3200_1mA Range = 2 F3200_100mA Range = 3)
digital_out_buffered_acquisition	Buffer Contiguous Data (1 = Enable, 0 = Disable)
int_out_acquisition_mode	Acquisition mode (0-7) (F3200_CustomAcquisitionMode = 0, F3200_InternalAcquisitionMode = 1, F3200_ExternalStartAcquisitionMode = 2, F3200_ExternalStartStopAcquisitionMode = 3, F3200_ExternalStartHoldAcquisitionMode = 4, F3200_ExternalWindowedAcquisitionMode = 5, F3200_SweepMode = 6 F3200_EncoderDrivenMode = 7)
int_out_adc_rate	ADC rate (Hz)
int_out_conversions_per_sample	Conversions per sample
int_out_start_trigger_source	Start trigger source (0-3) (InternalTriggerSource = 0, BNCTriggerSource = 1, OpticalTriggerSource, BNC_and_OpticalTriggerSource)
int_out_pause_trigger_source	Start trigger source (0-3) (InternalTriggerSource = 0, BNCTriggerSource = 1, OpticalTriggerSource, BNC_and_OpticalTriggerSource)

int_out_stop_trigger_source	Start trigger source (0-3) (InternalTriggerSource = 0, BNCTriggerSource = 1, OpticalTriggerSource, BNC_and_OpticalTriggerSource)
int_out_stop_count	Stop Count
int_out_burst_count	Burst Size (0 = unlimited)
int_out_register_offset	Offset from base_address to read or write
int_out_register_contents	Contents read from address, or contents to write to address
int_out_base_address	Base address (initialized as 0x08810000)
digital_out_register_command	Get register at address or Set register address with contents (1 = set, 0 = get)

9.6 F460

<loopcontroller type="F460" … > (G2 loop controller, direct support)

Wire	Description
analog_in_1	ADC channel 1 (volts)
analog_in_2	ADC channel 2 (volts)
analog_in_current_1	Current channel 1 (A)
analog_in_current_2	Current channel 2 (A)
analog_in_current_3	Current channel 3 (A)
analog_in_current_4	Current channel 4 (A)
analog_in_channel_1	Current channel 1 w/sensor compensations (A)
analog_in_channel_2	Current channel 2 w/sensor compensations (A)
analog_in_channel_3	Current channel 3 w/sensor compensations (A)
analog_in_channel_4	Current channel 4 w/sensor compensations (A)
analog_in_x_pos	Calculated x position

analog_in_y_pos	Calculated y position
analog_in_bias	Voltage
int_in_max_bias	Max bias readout
analog_in_process_value	Process value (servo)
analog_in_process_target	Process target (servo)
variant_in_data	4 elements of current data 4 elements of channel data 1 element of xpos 1 of ypos 4 elements of analog in data 4 elements of analog out data 1 element of high voltage
digital_out_initiate	Initiate measurement (1=initiate, 0 =abort)
int_out_range_1	Channel 1 range (0-3) (F460_1uA_Range = 0, F460_10uA_Range = 1, F460_100uA_Range = 2, F460_1mA_Range = 3)
int_out_range_2	Channel 2 range (same as channel 1)
int_out_range_3	Channel 3 range (same as channel 1)
int_out_range_4	Channel 4 range (same as channel 1)
int_out_monitor	Monitor out mode (0-3) (F460_Current = 0, F460_Sensor = 1, F460_Position = 2, F460_ManualOutput = 3)
analog_out_1	Analog out channel 1 (V)
analog_out_2	Analog out channel 2 (V)
analog_out_3	Analog out channel 3 (V)
analog_out_4	Analog out channel 4 (V)

analog_out_bias	External bias (V)
analog_out_integration_time	Integration time (seconds)
analog_out_dac_low_limit	DAC low limit (servo)
analog_out_dac_high_limit	DAC high limit (servo)
analog_out_kp	Kp PID parameter (servo)
analog_out_ki	Ki PID parameter (servo)
analog_out_low_current_limit	Low current limit (servo)
analog_out_reference	Reference (servo)
int_out_servo_period	Servo period (microseconds)
int_out_servo_mode	Servo mode (1-7, see device manual)
digital_out_servo_enable	Servo enable (1=enable, 0=disable)
int_out_register_offset	Offset from base_address to read or write
int_out_register_contents	Contents read from address, or contents to write to address
digital_out_register_command	Get register at address or Set register address with contents (1 = set, 0 = get)
int_out_base_address	Base address (initialized as 0x08810000)
string_in_firmware	Firmware Version
string_in_fpga	FPGA Version
string_in_serial_num	Serial Number
string_in_software_rev	Software Revision
string_in_secondary_fpga	Secondary FPGA Version
string_in_rtp_rev	RTP Revision
string_in_hardware_rev	Hardware Revision
int_out_position_calculation	(1 = Split Calculation, 0 = Quadrant Calculation)
digital_out_buffered_acquisition	Buffer Contiguous Data (1 = Enable, 0 = Disable)
int_out_acquisition_mode	Acquisition mode (0-5) (F460_CustomAcquisitionMode = 0,

	F460_InternalAcquisitionMode = 1, F460_ExternalStartAcquisitionMode = 2, F460_ExternalStartStopAcquisitionMode = 3, F460_ExternalStartHoldAcquisitionMode = 4, F460_ExternalWindowedAcquisitionMode = 5)
int_out_start_trigger_source	Start trigger source (0-1) (InternalTriggerSource = 0, BNCTriggerSource = 1)
int_out_pause_trigger_source	Start trigger source (0-1) (InternalTriggerSource = 0, BNCTriggerSource = 1)
int_out_stop_trigger_source	Start trigger source (0-1) (InternalTriggerSource = 0, BNCTriggerSource = 1)
int_out_bnc_start_gate	Trigger gate polarity (1 = Falling edge gate, 0 = Rising edge gate)
int_out_stop_count	Stop Count
int_out_burst_count	Burst Size
int_out_calibration_source	Calibration Source (0-2) (No Calibration Source = 0, Internal Low = 1, Internal High = 2)
int_out_calibration_channel	Channel to receive internal calibration source (0-3)
int_out_calibration_command	Calibrate Channel 0-3: F460 Channel -1: All Channels
digital_out_clear_calibrations	Clear Calibrations
variant_out_hvdac_calibration	3-element array [valid, gain, offset]
variant_out_hvadc_calibration	3-element array [valid, gain, offset]
variant_out_calibration_range_1	Calibration for range 1uA 9-element array: [valid, gain[0], offset[0], …, gain[3], offset[3]]

variant_out_calibration_range_2	Calibration for range 10uA (Same as range 1)
variant_out_calibration_range_3	Calibration for range 100uA (Same as range 1)
variant_out_calibration_range_4	Calibration for range 1mA (Same as range 1)
variant_out_analoginput_calibration	5-element array [valid, gain[0], offset[0], gain[1], offset[1]]
variant_out_analogoutput_calibration	9-element array [valid, gain[0], offset[0], …, gain[3], offset[3]]

9.7 C400

<board type="C400" … > (G2 loop controller, direct support)

Wire	Description
digital_in_running	Running state (1=running, 0=not running)
digital_in_paused	Paused state (1=paused, 0=not paused)
digital_in_stopped	Stopped state (1=stopped, 0=not stopped)
int_in_counts_n	Counts for the 4 channels (n=1-4)
analog_in_rate_n	Rate for the 4 channels (n=1-4)
analog_in_bias_n	Voltage readback for the 4 channels (n=1-4)
digital_out_initiate	Initiate/Abort acquisition control command (1=initate, 0=abort)
digital_out_polarity_n	Discriminator polarities for the 4 channels (n=1-4) (1=positive,0=negative)
digital_out_pulse_enable_n	Pulse control for the 4 channels (n=1-4) (1=enable,0=disable)
int_out_accum_mode	Accumulate mode (0-1) (C400_SingleIntegrations = 0, C400_AccumulatedIntegrations = 1)
int_out_trig_buf	Data buffer size
int_out_trig_bur	Burst size
int_out_trig_mode	Trigger mode (0-6)

	(C400_CustomAcquisitionMode = 0, C400_InternalAcquisitionMode = 1, C400_ExternalStartAcquisitionMode = 2, C400_ExternalStartStopAcquisitionMode = 3, C400_ExternalStartHoldAcquisitionMode = 4, C400_ExternalWindowedAcquisitionMode = 5, C400_DiscriminatorSweepMode = 6)
int_out_trig_source_start	Start trigger source (0-3) (InternalTriggerSource = 0, BNCTriggerSource = 1, OpticalTriggerSource = 2, BNC_and_OpticalTriggerSource = 3)
int_out_trig_source_stop	Stop trigger source (0-3) (InternalTriggerSource = 0, BNCTriggerSource = 1, OpticalTriggerSource = 2, BNC_and_OpticalTriggerSource = 3)
int_out_trig_source_pause	Pause trigger source (0-3) (InternalTriggerSource = 0, BNCTriggerSource = 1, OpticalTriggerSource = 2, BNC_and_OpticalTriggerSource = 3)
int_out_pulse_period	Pulse period (nsec)
int_out_pulse_width	Pulse width (nsec)
analog_out_low_limit_n	Discriminator low level (volts)
analog_out_high_limit_n	Discriminator high level (volts)
analog_out_bias_n	Voltage control for the 4 channels (volts)
analog_out_period	Integration period (sec)

9.8 B10

<board type="B10" … > (Fiber slave device, G1 loop controller support only)

Wire	Description
digital_in_1	TTL digital input channel 1
digital_in_2	TTL digital input channel 2
digital_in_3	TTL digital input channel 3
digital_in_4	TTL digital input channel 4
digital_in_5	TTL digital input channel 5
digital_in_6	TTL digital input channel 6
digital_in_7	TTL digital input channel 7
digital_in_8	TTL digital input channel 8
digital_out_1	TTL digital output channel 1
digital_out_2	TTL digital output channel 2
digital_out_3	TTL digital output channel 3
digital_out_4	TTL digital output channel 4
digital_out_5	TTL digital output channel 5
digital_out_6	TTL digital output channel 6
digital_out_7	TTL digital output channel 7
digital_out_8	TTL digital output channel 8

9.9 N2400

<board type="N2400" … > (Fiber slave device, G1 loop controller support only)

Wire	Description
digital_in_mode_switch_n	Mode switch position (n=1-24)
digital_in_relay_switch_n	Relay switch position (n=1-24)
digital_in_limit_neg_n	Limit switch neg state (n=1-24)
digital_in_limit_pos_n	Limit switch pos state (n=1-24)
digital_out_switch_relay_n	Switch relay (n=1-24)

9.10 H10

<board type="H10" … > (Fiber slave device, G1, G2 loopcontroller support)

Wire	Description
analog_in_1	Old probe: dBdT, New probe: voltage
analog_in_2	Field

9.11 H20

<board type="H20" … > (Fiber slave device, G1, G2 loopcontroller support)

Wire	Description
digital_out_initiate	Initiate command (1 = Initiate, 0 = Abort)
analog_in_probe_field_1	Field measured by probe 1 (G)
analog_in_probe_field_2	Field measured by probe 2 (G)
analog_in_probe_temperature_1	Temperature measured by probe 1 (C)
analog_in_probe_temperature_2	Temperature measured by probe 2 (C)
analog_in_adc_1	ADC1 measurement (V)
analog_in_adc_2	ADC2 measurement (V)
analog_out_dac_1	DAC (V) (Manual Mode Only)
analog_out_dac_2	DAC (V) (Manual Mode Only)
int_out_range_1	Probe 1 range 0: 1x 1: 4x 2: 10x 3: 40x
int_out_range_2	Probe 2 range Same mapping as int_out_range_1
int_out_mode_1	Probe 1 mode Mode_Manual = 0x0, Mode_Monitor = 0x1, Mode_DigitalClosedLoop = 0x2, Mode_AnalogClosedLoop = 0x3,

	Mode_FastMonitor = 0x4
int_out_mode_2	Probe 1 mode Same mapping as mode_out_1
analog_out_setpoint_1	Field Setpoint (G) (Digital Closed Loop Mode Only)
analog_out_setpoint_2	Field Setpoint (G) (Digital Closed Loop Mode Only)
analog_out_averaging_period	Averaging period (s)
int_out_stop_count	If < 1, no stop
string_in_serial_num_1	Probe 1 serial number
string_in_serial_num_2	Probe 2 serial number
analog_in_calib_temp_1	Calibration Temperature
analog_in_calib_temp_2	Calibration Temperature
analog_out_proportional_1	Proportional (Kp)
analog_out_proportional_2	Proportional (Kp)
analog_out_outmax_1	Out Max (V)
analog_out_outmax_2	Out Max (V)
digital_out_positive_output_1	Positive only output (0 = Positive only disabled 1 = Positive only enabled)
digital_out_positive_output_2	Positive only output (0 = Positive only disabled 1 = Positive only enabled)
analog_out_slew_limit_1	Slew Limit (V/s)
analog_out_slew_limit_2	Slew Limit (V/s)
analog_out_setpoint_gain_1	Setpoint Gain (G/V) (Analog Closed Loop Mode Only)
analog_out_setpoint_gain_2	Setpoint Gain (G/V) (Analog Closed Loop Mode Only)
string_in_h20_serial_num	H20 Serial Number
analog[2]_out_h20_A_field_1x	H20 Field 1x Calibration Side A [gain, offset] [0]: Gain

	[1]: Offset
analog[2]_out_h20_B_field_1x	H20 Field 1x Calibration Side B [0]: Gain [1]: Offset
analog[2]_out_h20_A_field_10x	H20 Field 10x Calibration Side A [0]: Gain [1]: Offset
analog[2]_out_h20_B_field_10x	H20 Field 10x Calibration Side B [0]: Gain [1]: Offset
analog[2]_out_h20_A_temp	Temp ADC Side A [0]: Gain [1]: Offset
analog[2]_out_h20_B_temp	Temp ADC Side B [0]: Gain [1]: Offset
analog[2]_out_h20_A_analoginput	H20 Analog Input Side A [0]: Gain [1]: Offset
analog[2]_out_h20_B_analoginput	H20 Analog Input Side B [0]: Gain [1]: Offset
analog[2]_out_h20_A_analogoutput	H20 Analog Output Side A [0]: Gain [1]: Offset
analog[2]_out_h20_B_analogoutput	H20 Analog Output Side B [0]: Gain [1]: Offset
analog[2]_out_probe_A_field_1x	Probe A Field 1x Calibration [0]: Gain [1]: Offset
analog[2]_out_probe_B_field_1x	Probe B Field 1x Calibration [0]: Gain [1]: Offset
analog[2]_out_probe_A_field_4x	Probe A Field 4x Calibration [0]: Gain [1]: Offset
analog[2]_out_probe_B_field_4x	Probe B Field 4x Calibration [0]: Gain [1]: Offset

9.12 I128

<loopcontroller type="I128" … > (G2 loop controller, direct support)

Wire	Description
analog[131]_in_current	128 elements of channel data (A) -10000 = overrange -20000 = unable to convert to A 1 element of HCC 1 element of seconds 1 element of nanoseconds
digital_in_connection_status	Status of connection between I128 and IG2 1: Connected 0: Disconnected
digital_in_measuring	Measuring readback
analog_in_bias	High voltage readback (volts)
analog_in_hcc	High current channel readback (A)
analog_in_range_current	Range (A)
analog_in_range_charge	Range (C)
analog_out_bias	High voltage command (volts)
analog_out_integration_time	Integration time (s)
int_out_conversions_per_sample	Conversions per sample (1-255)
int_out_range_hcc	High current channel range I128HCC_1uA_Range = 0x0, I128HCC_5uA_Range = 0x1, I128HCC_10uA_Range = 0x2, I128HCC_20uA_Range = 0x3,
digital_out_initiate	Initiate command (1 = Initiate, 0 = Abort)
digital_out_enable_external_bias	High voltage output (1 = enable, 0 = disable)
int_out_ion_chamber_mode	Ion chamber mode (0 = Standard Mode 1 = IC Mode)
analog_in_ic_temp	Ion Chamber Temperature (I)
analog_in_ic_pressure	Ion Chamber Pressure (PSI)

analog_in_ic_humidity	Ion Chamber Humidity (%RH)
analog_in_ic_reference	Ion Chamber Reference (V)
analog_out_dac_1	DAC out 1
analog_out_dac_2	DAC out 2
analog_in_adc_1	ADC In 1
analog_in_adc_2	ADC In 2
analog_out_averaging_period	Averaging Period (25 = 1e-4 250 = 1e-3 2500 = 1e-2 25000 = 1e-1 41675 = 1.667e-1 250000 = 1.0)
digital_out_zero_offset	Set the latest data sample as the background offset vector
digital_out_clear_offset_zero	Clear the background offset vector
string_in_firmware	Firmware Version
string_in_fpga	FPGA Version
string_in_serial_num	Serial Number
string_in_software_rev	Software Revision
string_in_secondary_fpga	Secondary FPGA Version
string_in_rtp_rev	RTP Revision
string_in_hardware_rev	Hardware Revision
int_out_filter	HCC Filter
digital_out_combine_channels	HCC Combine Channels Enable
analog_out_monitor_charge	HCC Monitor Charge
digital_out_align_channel_data	HCC Align with Channel Data Enable
analog_out_target_dose	Target Charge (nC) (This and next wire should be tested thoroughly)
digital_out_opt_enable	“Enable Beam” fiberoptic output
digital_in_opt_enabled	“Enable Beam” fiberoptic (1 = enabled, 0 = disabled)
int_in_digitals	Bit encoded digital inputs (0-15) bit0 = Digital 1

	bit1 = Digital 2 bit2 = Digital 3 bit3 = Digital 4
analog_in_hcc_processed	HCC data in Amps. May be processed (filtered)
digital_in_hcc_target_reached	(1 = target reached)
analog_in_hcc_dose	FPGA2 v1.4.10 and later: Dose accumulated on the HCC in coulombs. FPGA2 v1.4.9 and earlier: HCC dose remaining in coulombs.
int_out_start_trigger_source	Start trigger source (0-1) (InternalTriggerSource = 0, BNCTriggerSource = 1)
int_out_pause_trigger_source	Start trigger source (0-1) (InternalTriggerSource = 0, BNCTriggerSource = 1)
int_out_stop_trigger_source	Start trigger source (0-1) (InternalTriggerSource = 0, BNCTriggerSource = 1)
int_out_bnc_start_gate	Trigger gate polarity (1 = Falling edge gate, 0 = Rising edge gate)
int_out_stop_count	Stop Count (0 = unlimited)
int_out_burst_count	Burst Size (0 = unlimited)
int_out_register_offset	Offset from base_address to read or write
int_out_register_contents	Contents read from address, or contents to write to address
digital_out_register_command	Get register at address or Set register address with contents (1 = set, 0 = get)
int_out_base_address	Base address (initialized as 0x08810000)

int_in_interlock_readbacks	Bit encoded readback of interlock status
	(Least significant bits first)
	cmd:8;
	reserved1:1;
	reserved2:1;
	// High when CPLD is in fault state
	fault:1;
	enable_in:1;
	//Reflects the state of the Enabled line, as determined by the commands sent

	enabled:1;
	// High if the CPLD has failed
	cpld_stat_A:1;
	// High if the CPLD has failed
	cpld_stat_B:1;
	// Reflects the key switch state (high for Diag)
	keyswitch:1;
	// command sent for diag mode
	diag_mode:1;
	// High when relay is closed
	interlock_status:1;
	// Reflects the intended state of the relay, as determined by the commands sent
	interlock_command:1;
	// High when the CPLD should be in the initial state
	initial_state:1;
	reserved3:4;
	relay_command:1;
	reserved4:7;

digital_out_relay_enable	(1 = enable, 0 = disable)
digital_out_actuator_enable	(1 = enable, 0 = disable)
digital_out_test_ab	(0 = Test A, 1 = Test B) no readback
digital_out_interlock_enable	(0 = Enable, 1 = Disable) no readback
digital_out_calibration_source	Calibration Source I128_NoCalibrationSource = 0, I128_InternalCalibrationSource = 1,
int_out_calibration_channel	Calibration channel (1-129) 1-128 = strip select 129 = HCC
analog[260]_out_current_calibration	4 elements of valid (128 bits), followed by gain/offset pairs [valid x4, gain[0], offset[0], …, gain[127], offset[127]]
digital_out_buffered_acquisition	Buffer Contiguous Data (1 = Enable, 0 = Disable)
digital_out_clear_errors	Clear Device Errors
digital_out_set_interlock	Set interlock On or Off

string_out_configure_xml	Send filename of xml file to upload Readbacks: "InputFileName" at startup "success" if successful upload "failure" if failed
analog[256]_in_timeslice_data	Timeslice Database values configured in xml Max 256 values Convert floats to specified data types Initialized as 0 if < 256 Database values

9.13 IC101

<board type="IC101" … > (Fiber slave device, G1, G2 loopcontroller support)

Wire	Description
analog_in_current	Current input (A)
analog_in_accumulated_charge	Accumulated charge (C)
analog_out_range	Range select (A) and Readback
digital_out_initiate	Initiate command
digital_out_accumulate_charge	Accumulate command (1=start accumulation, 0=stop accumulation)
analog_out_integration_period	Set Integration Period (1e-4 to 1e0)
int_out_resolution	Set Resolution (16-20)
int_out_capacitor	Set Capacitor 0: small (100 pF by default) 1: large (3300 pF by default)
digital_out_calibrate	Calibrate
digital_out_save_calibration	Saves active calibration
digital_out_recall_calibration	Recalls stored calibration
digital_out_calibration_source	Calibration Source (On/Off)
int_out_external_bias	Set external Bias in volts If fitted; 0 to max or 0 to –max
int_out_external_bias_max	Set Max External Bias in volts
int_out_trigger_mode	Trigger Source 0: Internal

	1: External
int_in_trigger_count	Trigger Count
int_out_frequency_monitor_output_mode	Frequency Monitor Output Mode (1-3) 1: Absolute 2: Positive 3: Negative
int_out_frequency_monitor_mapping	Frequency Monitor Mapping (0-4) 0: 1MHz 1: 100kHz 2: 10kHz 3: 1kHz 4: 100Hz
digital_out_monitor_log_mode	Monitor Log Mode 0: Off 1: On
analog_out_monitor_scale	Monitor Scale
analog[5]_in_calibration	Calibration Factors 0: Valid bit 1: Gain for small capacitor 2: Offset for small capacitor 3: Gain for big capacitor 4: Offset for big capacitor
int_in_status_byte	Read digitals bit0 = measuring bit1 = waiting trigger bit2 = calibrated bit3 = HV enabled bit4 = external gate present bit5 = new data
string_in_serial_num	Serial Number

9.14 F100

<board type="F100" … > (Fiber slave device, G1, G2 loopcontroller support)

Wire	Description
analog_in_1	Current input (A)
digital_out_initiate	Initiate measurement (1=initiate, 0 =abort)
int_out_range	Range select (0-16) Sixteen total, thirteen unique

	(0=auto 1 = 1 µA 2 = 2 µA 3 = 5 µA 4 = 10 µA 5 = 10 µA 6 = 20 µA 7 = 50 µA 8 = 100 µA 9 = 100 µA 10 = 200 µA 11 = 500 µA 12 = 1 mA 13 = 1 mA 14 = 2 mA 15 = 5 mA 16 = 10 mA)

10. VIRTUAL DEVICES

(<interpreter> section)

Each device in this section is a custom or virtual device and is directly supported through IG2.

10.1 MEMBLOCK

<memblock type="memblock" size=”n” … >

Wire	Description
analog_out_n	General use analog output. (n=1-512)
digital_out_n	General use digital output. (n=1-512)
int_out_n	General use integer output. (n=1-512)
string_out_n	General use string output. (n=1-512)
analog_in_n	General use analog input. (n=1-512)
digital_in_n	General use digital input. (n=1-512)
int_in_n	General use integer input. (n=1-512)

string_in_n	General use string input. (n=1-512)

10.2 BPM (Detector)

<detector type="bpm" ... >

X AXIS = Channels 17-32
Y AXIS = Channels 1-16

Wire	Description
digital_out_position	Position control (0=out, non-zero=in)
analog_out_bias	High voltage control (V)
analog_in_bias	High voltage readback (V)
int_in_position	Position readback (0=out, non-zero=in)
analog_in_xcurrent_noscale	X-axis current readback (A) This value = sum of the X axis channels.
analog_in_ycurrent_noscale	Y-axis current readback (A) This value = sum of the Y axis channels.
analog_in_beamcurrent_noscale	Beam current readback (A) This value = (sum of X axis channels + sum of Y axis channels) / 2
analog_in_xcurrent	X-axis current readback (variable units, autoscaled) See analog_in_xcurrent_noscale.
analog_in_ycurrent	Y-axis current readback (variable units, autoscaled) See analog_in_ycurrent_noscale.
analog_in_beamcurrent	Beam current readback (variable units, autoscaled) See analog_in_beamcurrent_noscale.
variant_in_channels	32-element array of channel data (A)
analog_in_xpos_actual	Calculated x-axis position readback (mm) Gaussabola algorithm. Returns -10000 when calue cannot be calculated.

analog_in_ypos_actual	Calculated y-axis position readback (mm) Gaussabola algorithm. Returns -10000 when calue cannot be calculated.
analog_in_width_actual	Calculated x-axis width readback (mm) Gaussabola algorithm. Returns -10000 when calue cannot be calculated.
analog_in_height_actual	Calculated y-axes width readback (mm) Gaussabola algorithm. Returns -10000 when calue cannot be calculated.
analog_in_xpos_target	Target x-axis position (not currently used)
analog_in_ypos_target	Target y-axis position (not currently used)
analog_in_width_target	Target x-axis width (not currently used)
analog_in_height_target	Target y-axis width (not currently used)

10.3 ASCIICLIENT

<asciiclient type=" asciiclient " ip="TODO" port="TODO" proto="TODO" … >

Wire	Description
string_out_message	String sent to device
string_in_response	Response received from device
int_in_status	TODO
string_in_error_description	TODO

10.4 KOLLMORGEN (TELNET)

(Requires an Asciiclient)

< kollmorgentelnet type=" kollmorgentelnet" telnet_write_chn="TODO" telnet_read_chn="TODO" telnet_status_chn="TODO" telnet_error_chn="TODO" … >

Wire	Description
analog_out_position	MT.P (float)
int_out_table	MT.TNUM (integer)

int_out_profile	MT.CNTL (integer)
int_out_task	MT.NUM (integer)
int_out_cmdsource	DRV.CMDSOURCE (integer)
int_out_opmode	DRV.OPMODE (integer)
digital_out_stop	DRV.STOP (no argument)
digital_out_move	MT.MOV (no argument)
digital_out_home	HOME.MOV (no argument)
digital_out_enable	DRV.DIS + DRV.ENA (no argument)
analog_in_position	PL.FB
int_in_status	TODO
string_in_error_description	TODO

10.5 KOLLMORGEN (MODBUS)

< kollmorgen type=" kollmorgen" ip=”TODO” … >

Wire	Description
int_in_AIN_VALUE	Read the value of the analog input signal
int_out_DRV_CMDSOURCE	Sets the command source
int_out_DRV_OPMODE	Sets the drive operation mode
string_out_MT_CNTL	Sets motion task control word; active in opmode 2 only
int_out_MT_NUM	Sets the motion task number; active in opmode 2 only
int_out_MT_TNUM	Sets the motion task customer table number; active in opmode 2 only
digital_out_HOME_MOVE	Starts a homing procedure; active in opmode 2 only
digital_out_DRV_EN_DIS	Enable/disable drive command 1: Enable 0: Disable
digital_out_DRV_STOP	Stop command 1: Execute command

int_out_MOTOR_BRAKERLS	Allows a user to release or apply the motor brake
int_out_MT_MOVE	Starts a motion task; active in opmode 2 only
int_out_MT_SET	Sets the motion task in the drive; active in opmode 2 only
string_out_UNIT_PIN	Sets gear IN for the unit conversion
string_out_UNIT_POUT	Sets gear OUT for the unit conversion
analog_out_MT_P	Sets the motion task position; active in opmode 2 only
analog_in_PL_FB	Reads the position feedback value
analog_in_VL_CMD	Reads the actual velocity command; active in opmode 1 and opmode 2 only
int_in_DRV_MOTIONSTAT	Status bits: 0: Motion task is active 1: Home position found 2: Home routine finished 3: Homing active 4: Homing error occurred 5: Slave in electronic gearing 6: Electronic gearing active 7: Emergency stop in progress 8: Emergency stop procedure error 9: Service motion active 10: Motion task could not be activated 11: Motion task target position reached 12: Motion task target velocity reached 13: Motion task encountered an exception 14: Target position of motion task has been crossed 15: Actual position is within target position window 16: AKD Basic is executing a move 17: AKD Basic has completed a move 18: The fixed stop has been reached 19: The fixed stop has been passed 20: The axis broke off of the fixed position
int_in_MODBUS_DIO	Bits 0-7: Digital input ch.0 – ch.6 Bits 16-17: Digital output ch.0 – ch.1

int_in_MODBUS_DRVSTAT	Status Bits: 0: Drive active 1: STO status 2: Positive HW limit triggered 3: Negative HW limit triggered 4: Positive SW limit triggered 5: Negative SW limit triggered
string_in_modbus_status	Error from Modbus library Gets updated after each command
string_in_kollmorgen_status	Error from Kollmorgen Gets updated after each command

10.6 KEITHLEY

(manufacturing build only)

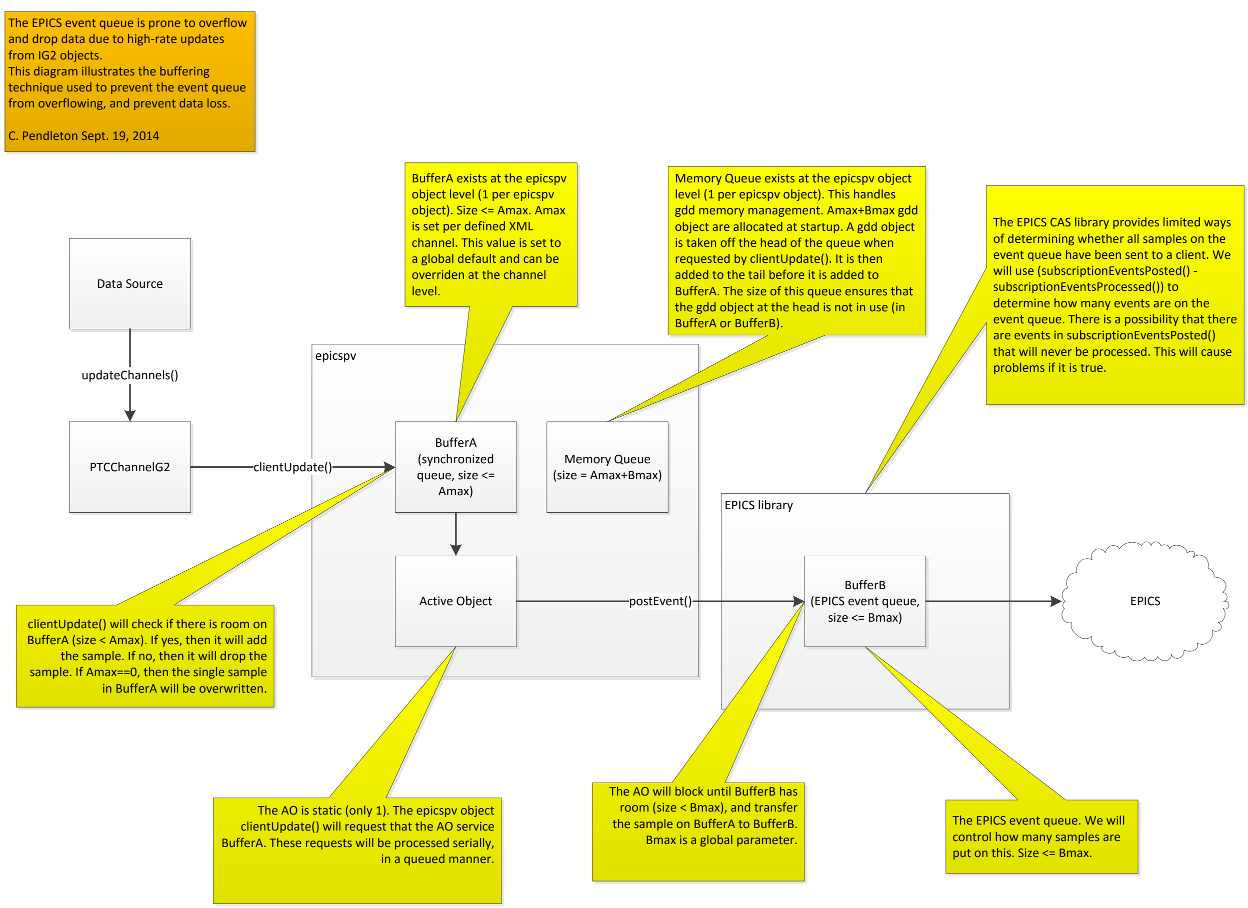
<keithley type="keithley" name="k238" id="0" address="16" >

Wire	Description
int_out_sourcemode	Source mode configuration (0=voltage, 1=current).
analog_out_sourcelevel	Source setpoint configuration.
analog_out_compliancevoltage	Compliance voltage configuration.
digital_out_initiate	Set operational mode (0=stop,1=run).
digital_in_error	Error state of last command sent (0=no error, 1=error).
string_out_command	Send string command. Max 40 characters.

11. APPENDIX 1 – ADVANCED CHANNEL BUFFERING

11.1 Design

See section 7.1.2 for introduction and basic options. The full design is shown below:



11.2 Global Options

There are 2 global buffering options:

<epicscas name="ecas" **aMax="10" bMax="20"** />

aMax is an optional parameter that determines the global value that all channels will default to. This can be overridden at the channel level (see 7.1.2). The default value of this parameter is 0 (unbuffered).

bMax determines the maximum allowed number of samples on the EPICS event queue. Changing this is not recommended. The default value is 10.