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| **Subgroup Name** | **Digital Subsystem** |
| **Subgroup Leader** | **Osamu Miyakawa****ICRR U-Tokyo** |

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| **Doc version** | **Date** | **Description** |
| Rev. A-0 | 2009-06-2 | Kick-off draft written in wiki format |
| Rev. A-1 | 2009-08-07 | Converted to MS-Word format |
| Rev. A-2 | 2010-04-15 | Fixed several parameters by the experience at CLIO digital system |
| Rev. A-3 | 2010-10-25 | Fixed several parameters for bLCGT |
| Rev. A-4 | 2010-12-22 | Fixed several parameters for bLCGT |

**Glossary**

|  |  |
| --- | --- |
| ADC | Analog to Digital Converter |
| DAC | Digital to Analog Converter |
| AA | Anti aliasing |
| AI | Anti imaging |
| UGF | unity gain frequency |
| IFO | interferometer |

1. **Definition of subsystem**

**This system provides the functions which digitalize analog sensing signals extracted from interferometers, produce signals in computers for controlling the interferometers and data acquisitions, and re-produce analog signals to actuate the interferometer.**

1. **Task area**

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| --- | --- | --- |
| **No.** | **Function** | **Description, equipments** |
| 1 | Digital control system | Main system. PC, ADC/DAC, AA/AI filter, whitening/dewhitening filter, real time OS, control software, monitor software, data storage. |
| 2 | Detector tuning system | Adjusts interferometer parameters. Tuning software. |
| 3 | Detector diagnosis system | Interferometer self diagnosis. Diagnosis software. |
| 4 | Long term monitor | Monitor software, data storage |
| 5 | Auto lock / auto alignment sequencer | Real time lock code (fast), auto lock and alignment scripts (slow). |
| 6 | Detector operation system for GW observation | Operators, operation scheduling, auto lock scripts. |
| 7 | GW search data calibration | Real time calibration shown in the control room. Projectors, calibration signals, real time calibration software |
| 8 | Real time data analysis | Real time data analysis shown in the control room. Projectors, real time data analysis software |

**3. Required specifications**

|  |  |  |
| --- | --- | --- |
| **Item** | **Requirements** | **Comment** |
| Sampling rate | >16kHz |  |
| ADC bit resolution | >=16bit |  |
| Dynamic range of input | >+/-15V | Half on differential |
| Dynamic range of output | >+/-10V | Half on differential |
| ADC noise | <3uV/rHz | Can be reduced by whitening filter |
| DAC noise | <3uV/rHz | Can be reduced by dewhitening filter |
| time delay | <100usec | To realize >200Hz UGF |
| Input channel numbers | >2048ch | (16kHz:>128ch, 2kzHz:>512ch, 64Hz>1024ch) |
| Output channel numbers | >512ch | for mirrors, seismic attenuators, PZTs |
| Stored channel numbers | 16kHz:>64ch, 2kzHz:>512ch, 64Hz>1024ch, 16Hz>10000ch | ~300TB/year |

**4. Interface between systems**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Item** | **Related sub-system** | **Requirements** | **Agreement** |
| \* | Sampling rate | Data acquisition, Data analysis, IFO control | 16384Hz(sampeled at 65536Hz and decimated to 16384Hz)option:up to 65536Hz for limited number of channels | not yet |
| \* | ADC bit resolution | Data acquisition, IFO | 16bit = 65536 | not yet |
|  | Number of stored channels | Data acquisition, Data analysis, IFO control | 16kHz:64ch, 2kHz:512ch, 64Hz:1024ch16Hz:16384 epics channels(see channel list) | not yet |
| \* | Data bit resolution in PC | Data acquisition | 32bit=4Byte | not yet |
|  | Data transfer rate | Data acquisition | 4MB/sec for 16kHz, 4MB/sec for 2kHz, 256kB/sec for 64Hz1MB/sec for 16HzTotal ~10MB/sec ~30GB/hour ~1TB/day ~300TB/year | not yet |
|  | Saved parameters (using conlog) | Data analysis, IFO control | See parameter list | not yet |
| \* | ADC dynamic range | IFO control | Full differential +/-10V = effective range +/-20V | not yet |
| \* | DAC dynamic range | IFO control | Full differential +/-5V = effective range +/-10V | not yet |
| \* | through delay | IFO control | 80usec | not yet |
| \* | ADC noise level | IFO control | 2uV/rHz | not yet |
| \* | DAC noise level | IFO control | 1.5uV/rHz | not yet |
| \* | AA filter noise level | IFO control | 0.1u V/rHz | not yet |
| \* | AI filter noise level | IFO control | 0.1u V/rHz | not yet |
| \* | whitening filter noise level | IFO control | 1n V/rHz | not yet |
| \* | dewhitening filter noise level | IFO control | 1n V/rHz | not yet |
| \* | whitening filter input impedance | IFO control | TBD | not yet |
| \* | dewhitening filter output impedance | IFO control | TBD | not yet |
|  | Connector shape | IFO control | D-SUB9 @ ADC in, DAC out, BO, AA in, AI out | not yet |
| \* | Power consumption | Infrastructure | For iLCGT:PC and cuircuits 30kWData storage 25kWClient PC 10kWOhters 1kWTotal 66kWFor bLCGTTBD | TasumiUchiyamaNot yet |
| \* | Waste heat and cooling | Infrastructure | TBD | not yet |
|  | Network capability | Infrastructure | 10Gbps Ether Net | not yet |
| \* | Optical fiber cable capability for real time PC, clock timing system | Infrastructure | TBD | not yet |
|  | GPS antenna | Infrastructure, Data acquisition | TBD |  |
|  | Location and space | Infrastructure, Data acquisition, IFO control | 5 racks at center room, 1 rack at X end room, 1 rack at Y end room for control system10 racks at data center | not yet |
| \* | Remote control switch | Vacuum, Infrasturucture | TTL(0V-5V) | not yet |
|  | Wireless LAN (digital system on laptop PC) | Infrastructure | IEEE802.11n(300Mbps) | not yet |
|  |  |  |  |  |

**↑ Mark \* on items which this subsystem needs to define.**

**5. Other related subsystems**

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **Function** | **Related sub-system** | **Description, equipments** |
| 1 | CCD monitor | IFO support |  |
| 2 | Inter lock | Infrastructure, IFO support |  |
| 3 | Entrance monitor system | Infrastructure |  |
| 4 | Real time monitors at control room | Infrastructure, IFO support, Data acquisition, Data analysis |  |
| 5 | Control PCs at control room | Infrastructure, Data analysis | Linux, 2-3 heads/PC, 10 PCs at least |

**6. Channel list**

a. ADC (total ~2048ch = 64cards or more)

|  |  |  |  |
| --- | --- | --- | --- |
| **Part** | **Channel point** | **Channel number** | **Description** |
| Laser |  | 10 |  |
| FSS | Power, REFL(DC, error), Trans | 10 |  |
| ISS | Power, REFL(DC, error), Trans | 10 |  |
| MZ | Power, REFL(DC, error), Trans | 10 |  |
| PMC | Power, REFL(DC, error), Trans | 10 |  |
| MC | Power, REFL(DC, error), Trans | 10 |  |
|  | WFS | 12(4quadxRF I&Q, DC)x2~30 |  |
| OMC | Power, REFL(DC, error), Trans | 10 |  |
|  | WFS | 4x2~10 |  |
| LSC | AS, ASDDM(2), REFL, REFLDDM(2), POX, POXDDM(2), POY, POB, SPOB, DC | 12x3(RF I&Q, DC)+1~50 |  |
| ASC | AS, REFL, POX | 12(4quadxRF I&Q, DC)x3x2WFS ~100 |  |
| Oplev | 14sus | 4quadx14 ~64 |  |
| QPD | LPOS, LANG, IPPOS, IPANG, TRX, TRY | 4quadx6=32 |  |
| SUS | 64ch(2ADCa)\*14sus | 896 | ~100Hz |
| Vacuum |  | 50 |  |
| Cryostat |  | 400 | ~16Hz |
| PEM |  | 100 |  |

b. DAC (total ~512ch = 32cards or more)

|  |  |  |  |
| --- | --- | --- | --- |
| **Part** | **Channel point** | **Channel number** | **Description** |
| PZT | Alignment for PMC, MZ, FSS, ISS, IMC | 5x2(pit, yawa)x2=10 |  |
| WFS | Alignment to PD at REFL, AS | 2(pit,yaw)x2PDx2port=8 |  |
| SUS | 32(2DACs)\*14 | 448 |  |
| Offset on analog servo | PMC, MZ, FSS, ISS, IMC, CARM | 10 |  |

c. BO (total ~2048bit = 64 cards or more)

|  |  |  |  |
| --- | --- | --- | --- |
| **Part** | **Channel point** | **Bit number** | **Description** |
| Laser | Modulation index | 2x4bit=8 |  |
| Gain slider | PMC, MZ, FSS, ISS, IMC, CARM etc. | 10x4bit=40 |  |
| Servo on/off | PMC, MZ, FSS, ISS, IMC, CARM etc. | 10x1bit=10 |  |
| LSC whitening+switch | AS, ASDDM(2), REFL, REFLDDM(2), POX, POXDDM(2), POY, POB, SPOB, DC | 12x3(RF I&Q, DC)+1x5bit~20 0 |  |
| ASC whitening+switch | AS, REFL, POX | 12(4quadxRF I&Q, DC)x3x2WFSx5bit ~500 |  |
| Oplev whitening+switch | 14sus | 4quadx14x5bit=~320 |  |
| QPD whitening+switch | LPOS, LANG, IPPOS, IPANG, TRX, TRY | 4quadx6QPDx5bit=120 |  |
| SUS dewhitening switch | 32(2DACs)\*14 | 448 |  |
| Vacuum switch |  | 100 |  |
| PEM |  | 100 |  |

\*1gain slider uses 16steps=4bit typically, so a 32bit card can handle 4 gain sliders.

**7. Saved DAQ channel list**

a. 16kHz (total 64ch)

|  |  |  |  |
| --- | --- | --- | --- |
| **Part** | **Channel point** | **Channel number** | **Description** |
| Laser | Output laser power[W] | 1 |  |
|  | IFO Input laser power[W] | 1 |  |
| MC | REFL | 1 |  |
|  | MC length feedback | 1 |  |
|  | MC frequency feedback | 1 |  |
| OMC | LSC | 2 | Error, feedback |
| LSC | I&Q for DARM, CARM, MICH, PRC, SRC, etc. | 15 |  |
|  | error, feedback for DARM, CARM, MICH, PRC, SRC, etc. | 15 |  |
| SUS | length \* 10 suspensions | 10 |  |
| Calibration |  | 5 |  |

b. 2kHz (total 128ch)

|  |  |  |  |
| --- | --- | --- | --- |
| **Part** | **Channel point** | **Channel number** | **Description** |
| ASC | WFS | 5x4quad x (RF+DC)~50 |  |
|  | Oplev | 14x3(pit,yaw,sum) x ~60 |  |
| OMC | ASC | 4x2(eerror, feedback)=8 |  |

c. 256Hz Long term monitor fast(total 512ch)

|  |  |  |  |
| --- | --- | --- | --- |
| **Part** | **Channel point** | **Channel number** | **Description** |
| Laser | Master laser power[W] | 2 |  |
|  | Output laser power[W] | 2 |  |
|  | IFO Input laser power[W] | 2 |  |
| Seismic | Room, outside, 3-axis | 30 |  |
| Tilt meter | Vertex, Main 4 suspensions | 5x2~10 | Vertex, IX, IY, EX, EY |
| SUS | Accelerometer | 32x14~400 |  |
| Sound | Microphone in Room, outside, table | 13 | 3+1(laser room) +5(each PD table), IX, IY, EX, EY, mine |

d. 16Hz Long term monitor slow and Epics channel data (total ~10000ch)

|  |  |  |  |
| --- | --- | --- | --- |
| **Part** | **Channel point** | **Channel number** | **Description** |
| Temperature[deg] | Laser crystal temperature[degree] and etc. | 10 |  |
|  | room | 10 | Vertex, laser, IX, IY, EX, EY, MX, MY |
|  | table | 8 | laser, MC, REFL, AS, pickoff x 2, end x 2 |
|  | cryostate | 96\*4=384 | Low temperature |
| Humidity[%] | rooms | 10 | Vertex, laser, IX, IY, EX, EY |
| Dust | rooms | 8 | Vertex, laser, IX, IY, EX, EY, MX, MY, mine |
| Air pressure | rooms | 8 | Vertex, laser, IX, IY, EX, EY, MX, MY, mine |
| Magnetic field | rooms | 8 | Vertex, laser, IX, IY, EX, EY, MX, MY, mine |
| Other EPICS channels | All data recorded by EPICS | 10000 | center, end, arm |

For PEM, see <http://gw.icrr.u-tokyo.ac.jp/JGWwiki/LCGT/PEM>

**8. Saved parameter list**

Gain, switch, offset, filter bank, filter on/off, matrix components and all other parameters on Epics channnel