EGO EUROPEAN GRAVITATIONAL OBSERVATORY

Suspension control algorithms – DAMPING: OpLev and WFS signals used for LC and AA + Top Stage ID control

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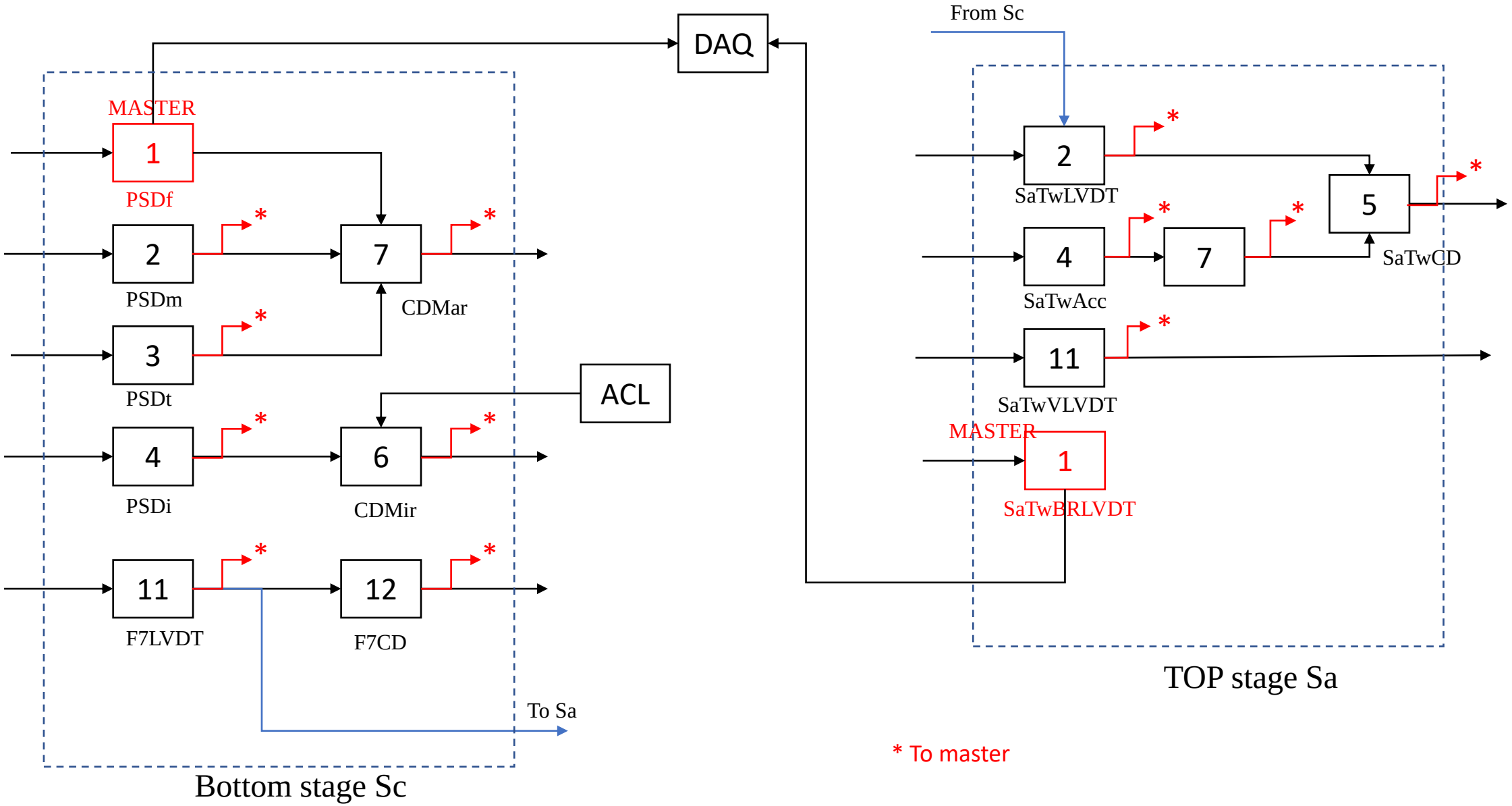
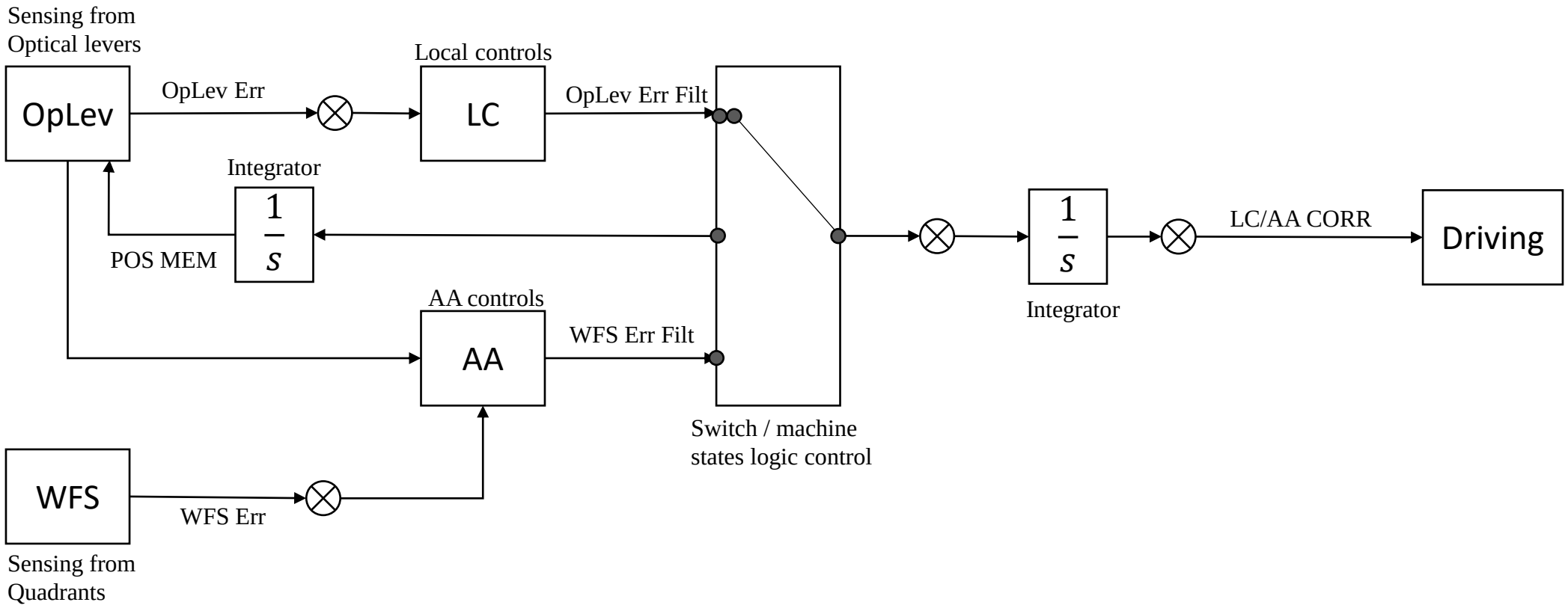
Block scheme communication of DSP boards



Angular control logic scheme (LC / AA)



Local controls algorithms

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Hardware implementation

WI_Mar.hrd

Ramp Time [5.00] Downsampling Factor [1]
Sampling Frequency [40000.000] Oversampling Factor [1]

Err sig filtered

Input	Output	Filename	GUARD	Gain	Gname	@Frequency	When
tyErr	tyLC_PD	PDty.flt	no	-0.04		1	after
tzErr	tzErr_PD1	PDtz4.flt	no	-0.035		1	after
tzErr	tzErr_PD2	PDtz.flt	no	-0.02		1	after
SWITCH	txErr_PD	txAAOn	no	1			
SWITCH	tyErr_PD	tyAAOn	no	1			
ADD	tzAAon		no	0			
SWITCH	tzErr_PD	tzAAon	no	1			
MIX	txErr_PDsw	mix5	no	1			
MIX	tyErr_PDsw	mix6	no	1			
txErr_PDsw	txErr_PID	intg.flt	no	1		1	after
tyErr_PDsw	tyErr_PID	intg.flt	no	1		1	after
tzErr_PDsw	tzErr_PID	intg.flt	no	1		1	after
MIX	tyCorMa	mix8	no	1			
MIX	tzCorMa	mix9	no	1			
RELAY	PSDm_R	REL1	no	1			
MIX	tyMar_R	mix1	no	1			
tyMar_R	tyMar_ABS	ABS	no	1			
tyMar_R	tyMar_INV	INV	no	1			
MIX	tyMar_Q	mix2	no	1			
RELAY	tyMar_SIGN	rel2	no	1			
tyMar_SIGN	tyMar_CRS	Coarse.flt	no	-1		0.1	after
MIX	tyCorMa	mix3	no	1			
MIX	tyCrsSw	swCrs-tyCrs	no	1			

Integrator -> correction

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Hardware implementation

WI_Mar.hrd

Ramp Time [5.00] Downsampling Factor [1]
Sampling Frequency [40000.000] Oversampling Factor [1]

Correction signal sent to Driving and MASTER

Input	Output	Filename	GUARD	Gain	Gname	@Frequency	When
MIX	tyCorMa	tyINT-LcOn	no	1			
ADD	txCorMa		no	0.568			
ADD	tyCorMa		no	-0.122			
ADD	tzCorMa		no	-0.063			
ADD	zCorMa		no	0			
ADD	xCorMa		no	0			
ADD	yCorMa		no	0			
txCorMa	Slot01_01	NULL	no	1			
tyCorMa	Slot01_02	NULL	no	1			
tzCorMa	Slot01_03	NULL	no	1			
zCorMa	txCorMa	NULL	no	-6e-05			
zCorMa	txCorMa	zc_txc.flt	no	0		10	after
zCorMa	tyCorMa	NULL	no	-8e-05			
zCorMa	tzCorMa	NULL	no	0.0115			
ADD	swyMir		no	0	MIR_Y_ON		
zCorMa1	yMarFeed	yCorr.flt	no	-0.5		6.9	after
MIX	yCorMaP	swy-feed	no	1			
CLIP	yCorMa	yCorMaP					
tzAAon	swtzMir	NULL	no	1			
zCorMa1	tzMarFeed	tzCorr.flt	no	0.5		9.8	after
MIX	tzCorMaP	swtz-feed	no	1			
CLIP	tzCorMa	tzCorMaP					
MAT		DRIVE_MA.mat					
ADD	MaL_Corr		no	0			
ADD	MaR_Corr		no	0			

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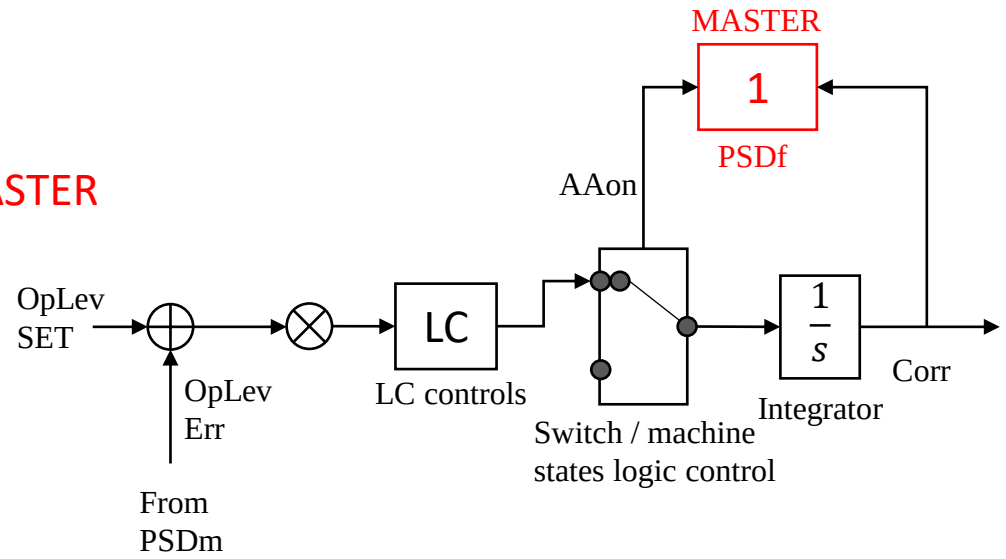
MaL_Corr	Slot06_02	NULL	no	1			
swzMir	Slot06_03	NULL	no	1			
zCorMa	Slot01_08	NULL	no	1			
txAAon	Slot01_0b	NULL	no	1			
tyAAon	Slot01_0c	NULL	no	1			
tzAAon	Slot01_0d	NULL	no	1			
MaBL_Mon	Slot01_11	NULL	no	1			
txMar	GUARD	guard_tx		1	MAR_GRD_TX		after
tyMar	GUARD	guard_ty		1	MAR_GRD_TY		after
tzMar	GUARD	guard_tz		1	MAR_GRD_TZ		after
ADD	MAR_GRD		yes	1	MAR_GRD_TG		
REL	Slot01_09	NULL	no	1			



SOFT and HARD control algorithms

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                        Hardware  implementation
                                                                 WE_PSDi.hrd

   Ramp Time          [5.00]                    Downsampling Factor [1]
   Sampling Frequency [40000.000]               Oversampling Factor [1]

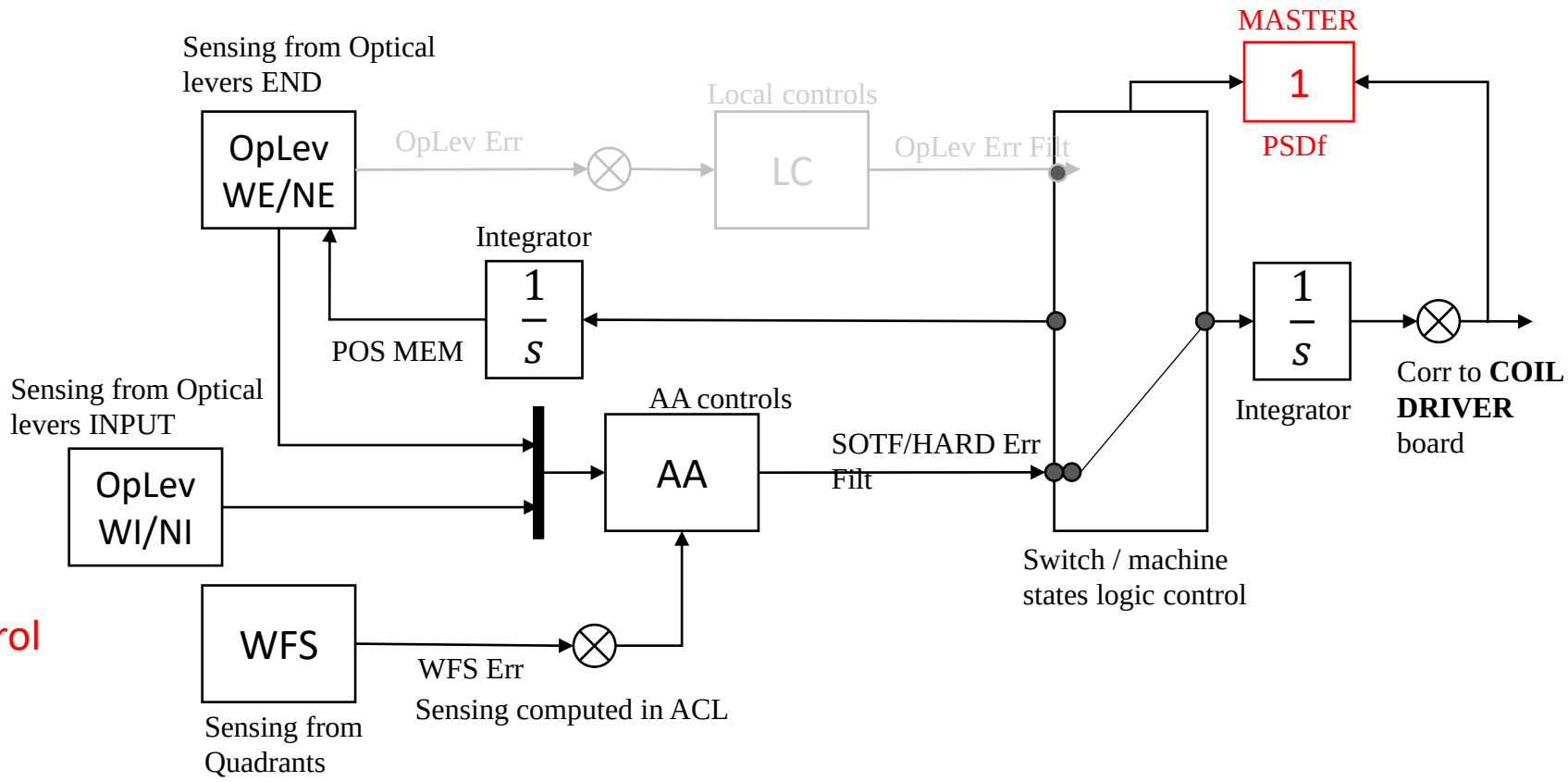
Input      Output       Filename     GUARD   Gain       Gname     @Frequency  When

wnoise     noise        lowpass.flt  no      0                    0          after
wnoise     noise        LowFnoise.flt no     0                    0          after
wnoise     noise        bpass.flt    no      0                    50         after
wnoise     noise        bpass2.flt   no      0                    5          after
wnoise     noise        bpass3.flt   no      0                    5          after
wnoise     noise        bpass190.flt no      0                    190        after
wnoise     noise        bpassTY.flt  no      0                    1          after
wnoise     noise        CALshape.flt no      0                    0          after
noise      Slot07_00          NULL   no      1
noise      Slot09_01          NULL   no      0
noise      Slot01_10          NULL   no      1
noise      Slot12_00          NULL   no      0
Slot07_00  txAA               NULL   no      1
Slot07_01  tyAA               NULL   no      1
Slot07_02  txMar              NULL   no      1
Slot07_03  tyMar              NULL   no      1
Slot09_00  AAN_txS            NULL   no      1
Slot09_01  AAN_tyS            NULL   no      1
Slot01_00  txErrWI            NULL   no      1
Slot01_01  tyErrWI            NULL   no      1
Slot01_02  AAtxWIon           NULL   no      1
Slot01_03  AAtyWIon           NULL   no      1
txMar      WA_Ctx             NULL   no      1
txErrWI    WA_Ctx             NULL   no      1
tyMar      WA_Cty             NULL   no      1
tyErrWI    WA_Cty             NULL   no      -1
WA_Cty     ErrPost            NULL   no      0
WA_Ctx     WA_CtxC1     txComm8.flt  no      -0.02                1          after
WA_Cty     WA_CtyC1     tyComm5.flt  no      -0.043               1          after
WA_Ctx     WA_CtxC2     txComm7.flt  no      -0.0135              1          after
WA_Cty     WA_CtyC2     tyComm4.flt  no      -0.03                1          after
ADD        swC12tx                   no      0
ADD        swC12ty                   no      0
SWITCH     WA_CtxC      swC12tx      no      1
SWITCH     WA_CtyC      swC12ty      no      1
txAA       txAAPRE            NULL   no      1
```

IN and END OpLev signals are recombined to obtain SOFT error signal

WA SOFT control filters

SOFT and DIFF/COMM signals are recombined and processed in WE/NE_PSDi



SOFT and HARD control algorithms

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                        Hardware  implementation
                                                                 WE_PSDi.hrd

   Ramp Time          [5.00]                    Downsampling Factor [1]
   Sampling Frequency [40000.000]               Oversampling Factor [1]

Input      Output       Filename     GUARD   Gain      Gname     @Frequency  When

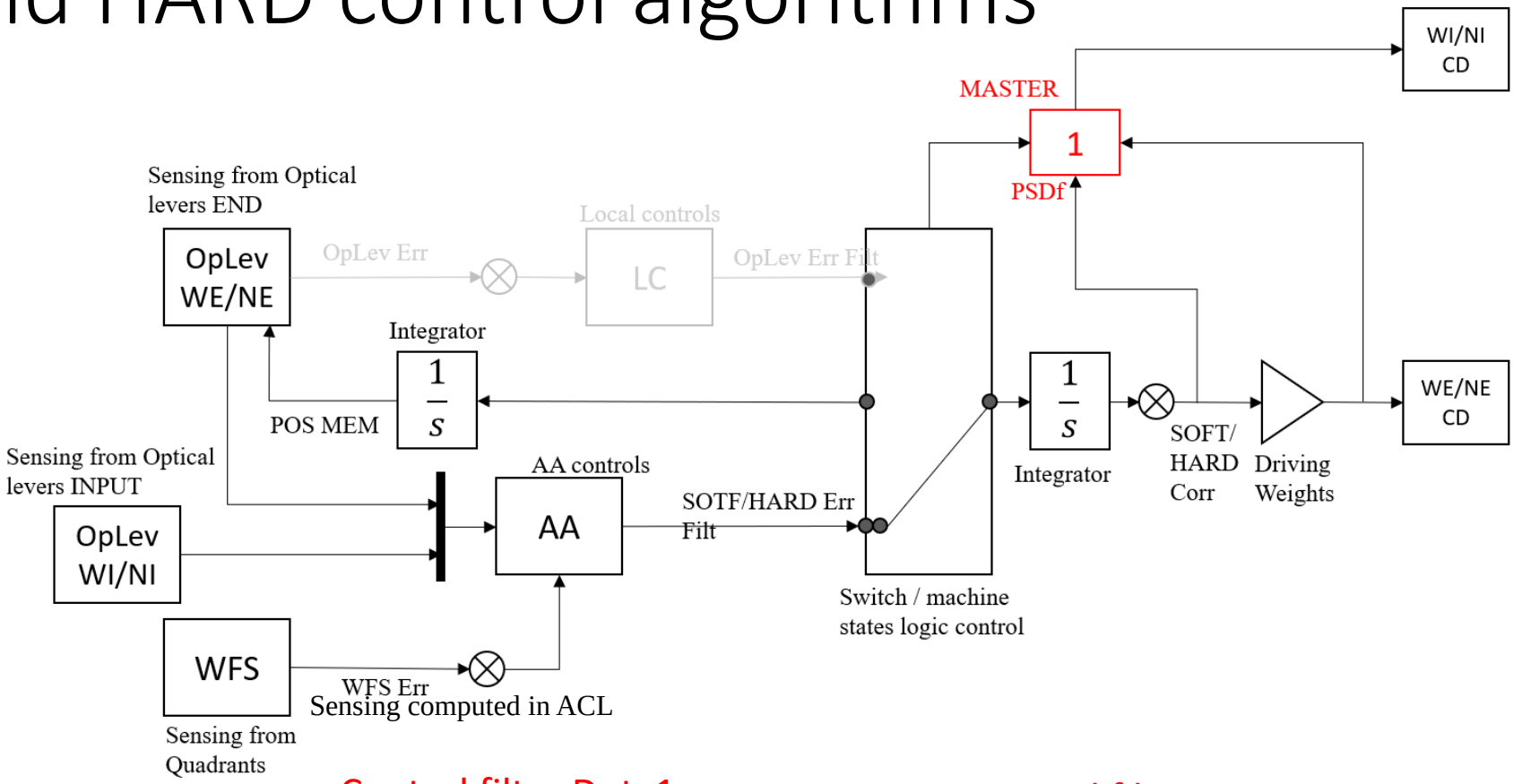
tyAA       tyAAPRE          NULL     no      1
noise      txAA             NULL     no      0
noise      tyAA             NULL     no      0
txAA       ErrPost          NULL     no      0
tyAA       ErrPost          NULL     no      1
txAA       txAAp1     txCorr17.flt   no      -0.093          1          after
tyAA       tyAAp1     tyCorr14.flt   no      -0.04           1          after
txAA       txAAp2     txCorr18.flt   no      -0.2            1          after
tyAA       tyAAp2     tyCorr17.flt   no      -0.04           1          after
ADD        swAA12tx                  no      0          SW_DBTX
ADD        swAA12ty                  no      1          SW_DBTY
SWITCH     AA_DtxC    swAA12tx       no      1
SWITCH     AA_DtyC    swAA12ty       no      1
AA_DtxC    Slot01_0e        NULL     no      1
AA_DtyC    Slot01_0f        NULL     no      1
Slot01_04  AA_CtxC          NULL     no      1
Slot01_05  AA_CtyC          NULL     no      1
AA_DtxC    WA_DtxC          NULL     no      1
AA_CtxC    WA_DtxC          NULL     no      1
AA_DtyC    WA_DtyC          NULL     no      1
AA_CtyC    WA_DtyC          NULL     no      -1
ADD        DtxWE                     no      1
ADD        DtyWE                     no      1
AAtxWIon   DtxWE            NULL     no      -0.5
AAtxWIon   CtxWE            NULL     no      0.47
AAtxWIon   DtxWI            NULL     no      -0.5

Input      Output       Filename     GUARD   Gain      Gname     @Frequency  When

AAtxWIon   CtxWI            NULL     no      0.53
AAtyWIon   DtyWE            NULL     no      -0.5
AAtyWIon   CtyWE            NULL     no      0.46
AAtyWIon   DtyWI            NULL     no      0.5
AAtyWIon   CtyWI            NULL     no      -0.54
MIX        AAtxWE     DtxWE          no      1
MIX        AAtxWE     CtxWE          no      1
MIX        AAtxWI     DtxWI          no      1
MIX        AAtxWI     CtxWI          no      1
MIX        AAtyWE     DtyWE          no      1
MIX        AAtyWE     CtyWE          no      1
MIX        AAtyWI     DtyWI          no      1
MIX        AAtyWI     CtyWI          no      1
txAAPRE    Slot01_07        NULL     no      1
tyAAPRE    Slot01_08        NULL     no      1
AAtxWI     Slot01_09        NULL     no      1
AAtyWI     Slot01_0a        NULL     no      1
WA_CtxPRE  Slot01_0b        NULL     no      1
WA_CtyPRE  Slot01_0c        NULL     no      1
ErrPost    Slot01_0d        NULL     no      1
AAtxWE     Slot07_01        NULL     no      1
AAtyWE     Slot07_02        NULL     no      1
```

Dp filters: possibility to switch online between 2 filters*

Driving coeff.



Control filter Dpty1

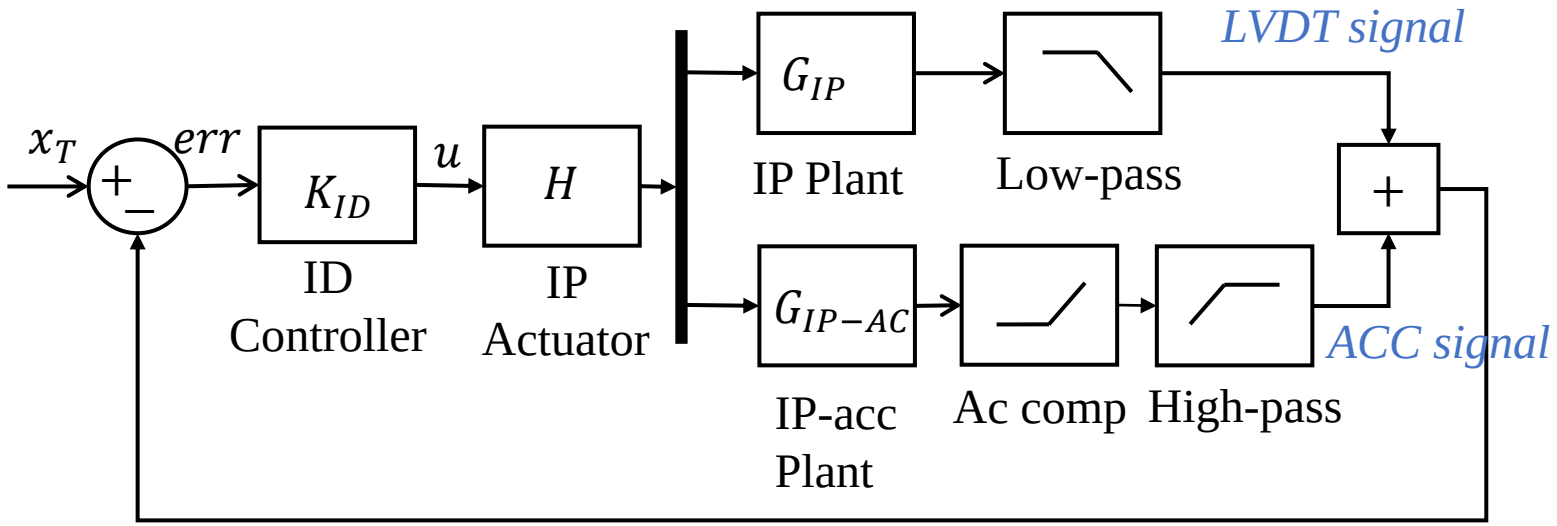
```
                                                                 tyCorr14.flt
Complex zeroes  frequency   0.035          Q       0.53
Real    zeroes  frequency   0.12           Q       0.47
Complex zeroes  frequency   0.31           Q       0.98
Complex zeroes  frequency   1.36           Q       3.2
Complex zeroes  frequency   1.68           Q       0.61
Complex zeroes  frequency   3.27           Q       0.54
Complex zeroes  frequency   9.7            Q       1.5
Complex zeroes  frequency   12.7           Q       3.3
Complex poles   frequency   0.04           Q       0.93
Complex poles   frequency   0.17           Q       2.14
Complex poles   frequency   2.13           Q       0.53
Complex poles   frequency   3.41           Q       0.69
Complex poles   frequency   8.64           Q       0.88
Complex poles   frequency   12.8           Q       0.97
Complex poles   frequency   9.6            Q       1
Complex poles   frequency   13.7           Q       0.71
Complex zeroes  frequency   6.9            Q       200
Complex poles   frequency   6.9            Q       20
```

*

Control filter Dpty2

```
                                                                 tyCorr17.flt
Complex zeroes  frequency   0.035          Q       0.53
Real    zeroes  frequency   0.12           Q       0.47
Complex zeroes  frequency   0.31           Q       0.98
Complex zeroes  frequency   1.36           Q       3.2
Complex zeroes  frequency   1.68           Q       0.61
Complex zeroes  frequency   3.27           Q       0.54
Complex zeroes  frequency   20             Q       1.5
Complex poles   frequency   0.04           Q       0.93
Complex poles   frequency   0.17           Q       2.14
Complex poles   frequency   2.13           Q       0.53
Complex poles   frequency   3.41           Q       0.69
Complex poles   frequency   9              Q       0.7
Complex poles   frequency   12             Q       0.7
Complex poles   frequency   15             Q       0.8
Complex zeroes  frequency   6.9            Q       200
Complex poles   frequency   6.9            Q       20
```

Top Stage Inertial Damping algorithm



Top Stage Inertial Damping algorithm

```
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                Virgo Inertial damping on [ 172.16.2.140 ]        Page 3

                        Hardware  implementation
                                                          WE_ID_Diag.hrd

   Ramp Time          [5.00]                  Downsampling Factor [1]
   Sampling Frequency [10000.000]             Oversampling Factor [1]

Input      Output      Filename     GUARD   Gain       Gname     @Frequency  When

Slot07_03  a3              NULL     no      1
Slot07_04  ka1             NULL     no      1
Slot07_05  ka2             NULL     no      1
Slot07_06  ka3             NULL     no      1
ADD        swk                      no      1
SWITCH     acc1        sw1          no      1
SWITCH     acc2        sw2          no      1
SWITCH     acc3        sw3          no      1
Slot02_04  vl0             NULL     no      1
Slot04_01  va1             NULL     no      1
Slot04_02  va2             NULL     no      1
va1        va1F        vAcc_Resp1.flt no     2.0312e+06           1           after
va2        va2F        vAcc_Resp2.flt no     -1.2583e+0           1           after
ADD        l1                       no      -6049
ADD        l2                       no      -6313
ADD        l3                       no      5775
l1         l1c             NULL     no      -0.7545
l2         l2c             NULL     no      -0.7981
l3         l3c             NULL     no      0.6242
MAT                L.mat
vl0        yL              NULL     no      1
ADD        crad                     no      1
MIX        xLC1        xL-crad      no      0.01
xLC1       xLC             NULL     no      1
xLC1       xLC         LPCR.flt     no      0                    0           after
MIX        zLC1        zL-crad      no      0.01

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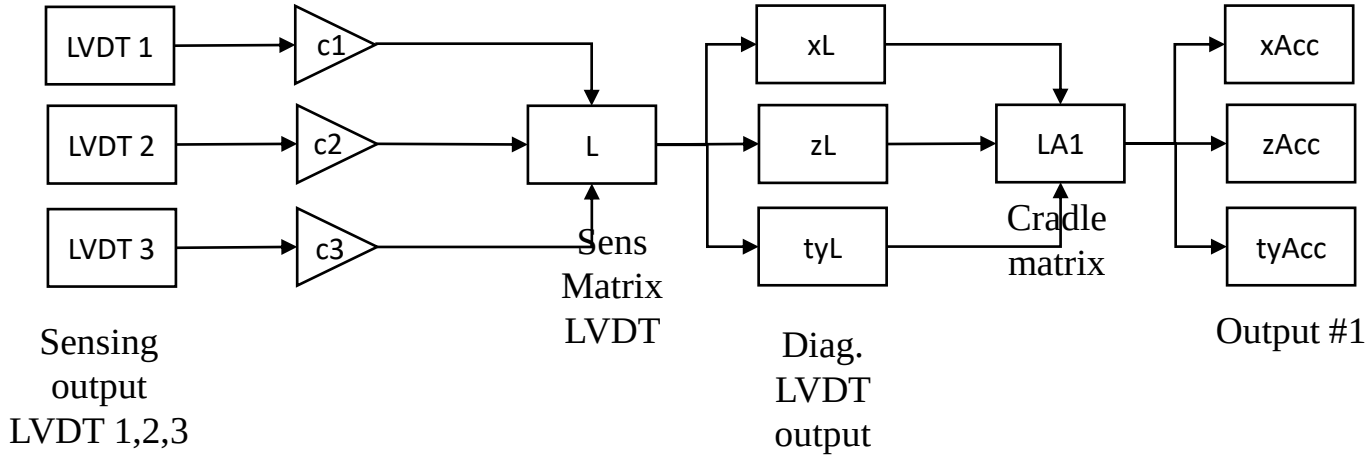

Sensing matrix LVDT

```
                                                          L.mat

   l1c          l2c          l3c

 0.665        -0.2922      -0.3728        xL
-0.0465        0.5992      -0.5527        zL
 0.3831        0.3831       0.3831        tyL
```

Top Stage Inertial Damping algorithm

```
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                    Hardware  implementation
                                                          WE_ID_Diag.hrd

   Ramp Time          [5.00]                  Downsampling Factor [1]
   Sampling Frequency [10000.000]             Oversampling Factor [1]

Input      Output      Filename     GUARD   Gain       Gname     @Frequency  When

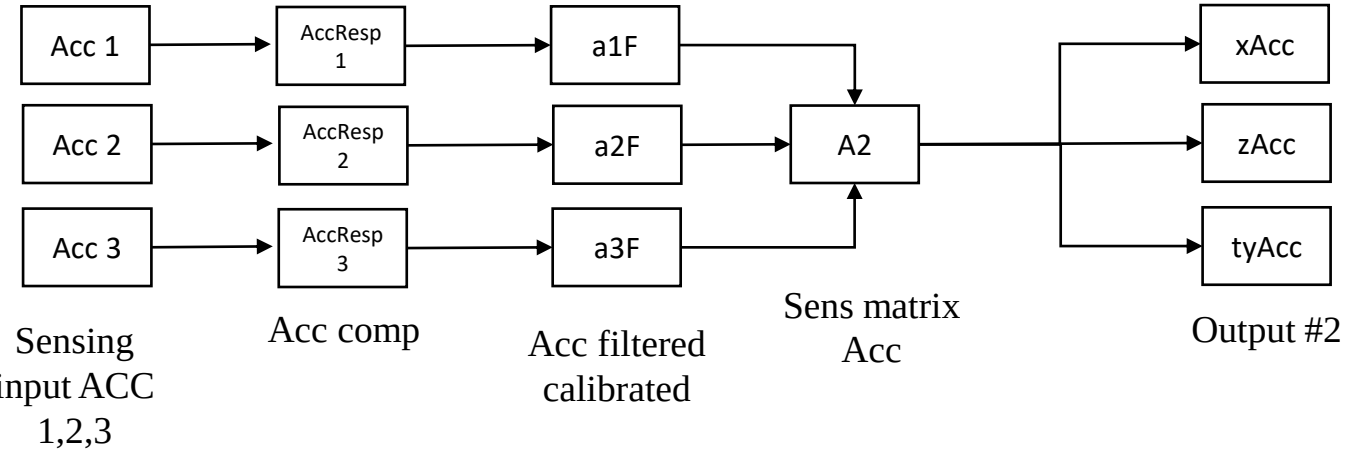
zLC1       zLC             NULL     no      1
zLC1       zLC         LPCR.flt     no      0                      0          after
MIX        tyLC1       tyL-crad     no      0.01
tyLC1      tyLC            NULL     no      1
tyLC1      tyLC        LPCR.flt     no      0                      0          after
MAT                    LA1.mat
acc1       a1F1        Acc_Resp1.flt  no    -2.0407e+0             0          after
acc1       a1F2        Acc_Resp1b.flt no    -883490                0          after
acc2       a2F         Acc_Resp2.flt  no    -1.2138e+0             0          after
acc3       a3F         Acc_Resp3.flt  no    -995200                0          after
ADD        swA1F                      no    0
SWITCH     a1F         a1F1_a1F2      no    1
MAT                    A2.mat
MAT                    vA.mat
```

```
                                                                    LA1.mat

 xLC          zLC          tyLC

1.7628       -0.0601      -0.463          xAcc
-0.3209      1.7954       0.1072          zAcc
0.0332       0.0369       0.0162          tyAcc
```

CRADLE matrix



Sensing matrix ACC

```
                                                                    A2.mat

 a1F          a2F          a3F

0.3132       -0.296       -0.0155         xAcc
-0.1849      -0.1578      0.3459          zAcc
0.2926       0.3597       0.3468          tyAcc
```

Top Stage Inertial Damping algorithm

BLENDING strategy

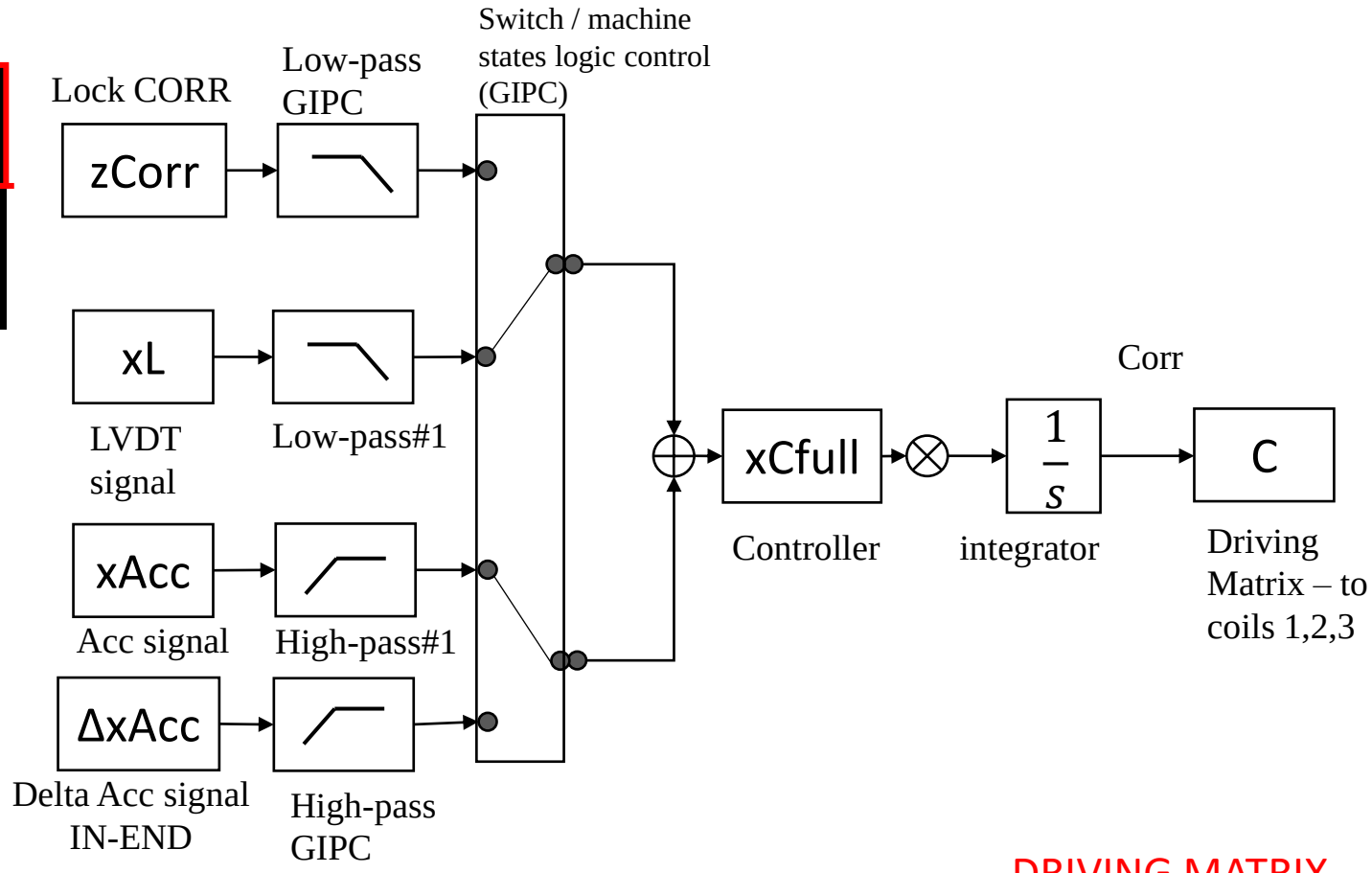
xLE	xLA1	elleDIFF.flt	no	1	0
xAcc	xLA1	accaDIFF.flt	no	2.53e-08	1000
xLE	xLA2	elle75.flt	no	1	0
xAcc	xLA2	acca75.flt	no	2.53e-08	1000
zLE	zLA1	elleDIFF.flt	no	1	0
zAcc	zLA1	accaDIFF.flt	no	2.53e-08	1000
zLE	zLA2	elle75.flt	no	1	0
zAcc	zLA2	acca75.flt	no	2.53e-08	1000
tyLE	tyLA1	elle90.flt	no	1	0

SWITCH	xLA	GIPC	no	1
xLA	fbxf1	xCfull.flt	no	0.7
xLA	fbxf2	xCfull1.flt	no	1
zLA	fbzf1	zCfull.flt	no	0.7
zLA	fbzf2	zCfull1.flt	no	1
tyLA	fbtyf	tyCfull.flt	no	0.3
yLA	fbyf	yCfull.flt	no	0.04
xLE	fbxi	xCinit.flt	no	0.05
zLE	fbzi	zCinit.flt	no	0.05
tyLE	fbtyi	tyCinit.flt	no	0.03
yLE	fbyi	yCinit.flt	no	0.02
ADD	swfb12		no	1

Control filter ID

fbxc	fbx	intg.flt	no	1
fbzc	fbz	intg.flt	no	1
fbtyc	fbty	intg.flt	no	1
fbyc	fby	intg.flt	no	1
MIX	xC	dcOn-fbx	no	1
MIX	zC	dcOn-fbz	no	1
MIX	tyC	dcOn-fbty	no	1
MIX	yCorr	dcOn-fby	no	1
ADD	xC		no	0
ADD	zC		no	0
ADD	tyC		no	0
ADD	yCorr		no	0

Corr generation after integral



DRIVING MATRIX

C.mat

xC	zC	tyC	
1.6002	0.734	0.22	coil1
-1.4364	0.9468	0.2378	coil2
-0.1773	-1.6253	0.2639	coil3

Suggestions

1. Software, from the **users** pov, is quite intuitive (at least from my personal opinion): input-output relationship through basic or custom functions (simulink like).
2. Main functions for control operations are already implemented. Given interaction among subsystems this can be improved.
3. Drawback: **lack of documentation**. Simplest actions cannot be performed unless experts explain to you how to do them (e.g. even downloading one DSP board after one modification).
4. **User friendly development can be improved** by (just to name a few):
    1. Detailed documentation;
    2. Traceability of actions;
    3. More probes (?) – possibility to output more data.