PID Control Implementation Record

1. Variable Operations Record

Low-Pass Filter Coefficient Calculation

case 5′d21:

```
TwoTau = 2 * iHsVd_LPF_tau
TwoTau_A_T = TwoTau + iHsCtrl_SplIntv
TwoTau_S_T = TwoTau - iHsCtrl_SplIntv
HsVd_Coeff = iHsCtrl_SplIntv / TwoTau_A_T
```

case 5′d29:

```
HsVd_LPF_Coeff1 = TwoTau_S_T / TwoTau_A_T
```

Low-Pass Filter Operations

case 9′d21:

```
HsVd_Coeff_M_HsVd_VECT6_0 = iHsVd_VECT6[0] * HsVd_Coeff
HsVd_Coeff_M_HsVd1_VECT6_0 = HsVd1_VECT6[0] * HsVd_Coeff
```

case 9′d22:

```
HsVd_LPF_Coeff1_M_HsVd1_LPF_VECT6_0 = HsVd1_LPF_VECT6[0] * HsVd_LPF_Coeff1
```

case 9′d35:

```
HsVd_ForLPF_Sum_VECT6_0 = HsVd_Coeff_M_HsVd_VECT6_0 + HsVd_Coeff_M_HsVd1_VECT6_0
HsVd_LPF_VECT6_0 = HsVd_ForLPF_Sum_VECT6_0 + HsVd_LPF_Coeff1_M_HsVd1_LPF_VECT6_0
```

PID Coefficient Calculation

case 5′d0:

```
HsIgain_M_SplIntvO2_VECT6[0] = iHsIgain_VECT6[0] * iHsCtrl_SplIntvO2
HsDgain_D_SplIntvO2_VECT6[0] = iHsDgain_VECT6[0] / iHsCtrl_SplIntvO2
HsIgain_M_SplIntv_VECT6[0] = iHsIgain_VECT6[0] * iHsCtrl_SplIntv
```

case 5′d7:

```
Intm_Coeff_VECT6[0] = HsDgain_D_SplIntvO2_VECT6[0] + HsIgain_M_SplIntvO2_VECT6[0]
```

case 5′d13:

```
FourHsDgain_D_SplIntv_VECT6[0] = 2 * HsDgain_D_SplIntvO2_VECT6[0]
```

case 5′d15:

```
oHsCoeff_VECT6[0] = Intm_Coeff_VECT6[0] + iHsPgain_VECT6[0]
oHsCoeff1_VECT6[0] = Intm_Coeff_VECT6[0] - iHsPgain_VECT6[0]
```

case 5′d27:

```
oHsCoeff2_VECT6[0] = HsIgain_M_SplIntv_VECT6[0] - FourHsDgain_D_SplIntv_VECT6[0]
```

Error Calculation

case 9′d56:

```
oHsVerr_VECT6[0] = HsVd_LPF_VECT6[0] - iHsVm_VECT6[0]
```

case 9'd63:

```
oHsVctrlFF_VECT6[0] = HsVd_LPF_VECT6[0] / iHsFFgain_VECT6[0]
```

PID Control Calculation

case 9'd64:

```
HsVerr_M_HsCoeff_VECT6[0] = oHsVerr_VECT6[0] * oHsCoeff_VECT6[0]
```

case 9'd70:

```
HsVerrHsCoeff_A_HsVctrl2_VECT6[0] = HsVerr_M_HsCoeff_VECT6[0] +
HsVctrlCompl_2_VECT6[0]
```

case 9'd76:

```
HsVerr1_M_HsCoeff1_VECT6[0] = HsVerr1_VECT6[0] * oHsCoeff1_VECT6[0]
```

case 9'd82:

```
HsVerr2_M_HsCoeff2_VECT6[0] = HsVerr2_VECT6[0] * oHsCoeff2_VECT6[0]
```

case 9'd90:

```
HsVerr1HsCoeff1_A_HsVerr2HsCoeff2_VECT6[0] = HsVerr2_M_HsCoeff2_VECT6[0] +
HsVerr1_M_HsCoeff1_VECT6[0]
```

case 9'd98:

```
oHsVctrlCompl_VECT6[0] = HsVerr1HsCoeff1_A_HsVerr2HsCoeff2_VECT6[0] +
HsVerrHsCoeff_A_HsVctrl2_VECT6[0]
```

```
oHsVctrlTot_VECT6[0] = oHsVctrlCompl_VECT6[0] + oHsVctrlFF_VECT6[0]
```

2. Difference Equation Derivation

Low-Pass Filter Difference Equation

$Vd_{LPF}[n] = \frac{T}{2\tau+T} \cdot (Vd[n] + Vd[n-1]) + \frac{2\tau-T}{2\tau+T} \cdot Vd_{LPF}[n-1]$

Where:

- T = iHsCtrl_SplIntv (Sampling period)
- τ = iHsVd_LPF_tau (Filter time constant)
- HsVd_Coeff = $T/(2\tau+T)$
- HsVd_LPF_Coeff1 = $(2\tau-T)/(2\tau+T)$

PID Control Difference Equation

$e[n] = Vd_{LPF}[n] - Vm[n]$

$u_{PID}[n] = \big(K_p + K_i \cdot T/2 + K_d/(T/2)\big) \cdot e[n] \quad +\big(K_i \cdot T/2 + K_d/(T/2) - K_p\big) \cdot e[n-1]$
$\quad +(K_i \cdot T - 4 \cdot K_d/T) \cdot e[n-2] \quad +u[n-2]$

Where:

- K_p = iHsPgain_VECT6[0] (Proportional gain)
- K_i = iHsIgain_VECT6[0] (Integral gain)
- K_d = iHsDgain_VECT6[0] (Derivative gain)
- T = iHsCtrl_SplIntv (Sampling period)

Coefficient Mapping:

- oHsCoeff_VECT6[0] = $K_p + K_i \cdot T/2 + K_d/(T/2)$
- oHsCoeff1_VECT6[0] = $K_i \cdot T/2 + K_d/(T/2) - K_p$

- oHsCoeff2_VECT6[0] = $K_i \cdot T - 4 \cdot K_d/T$

Total Control Output

$u_{total}[n] = u_{PID}[n] + u_{FF}[n]$

Where:
- $u_{FF}[n] = Vd_{LPF}[n]/FFgain$ (Feedforward control)
- FFgain = iHsFFgain_VECT6[0]

Timing Marks

case 5′d0 → case 5′d10: PID coefficient calculation completed

case 5′d21 → case 5′d29: Low-Pass Filter coefficient calculation completed

case 9′d56 → case 9′d98: PID control operation completed, output oHsVctrlTot_VECT6[0]