



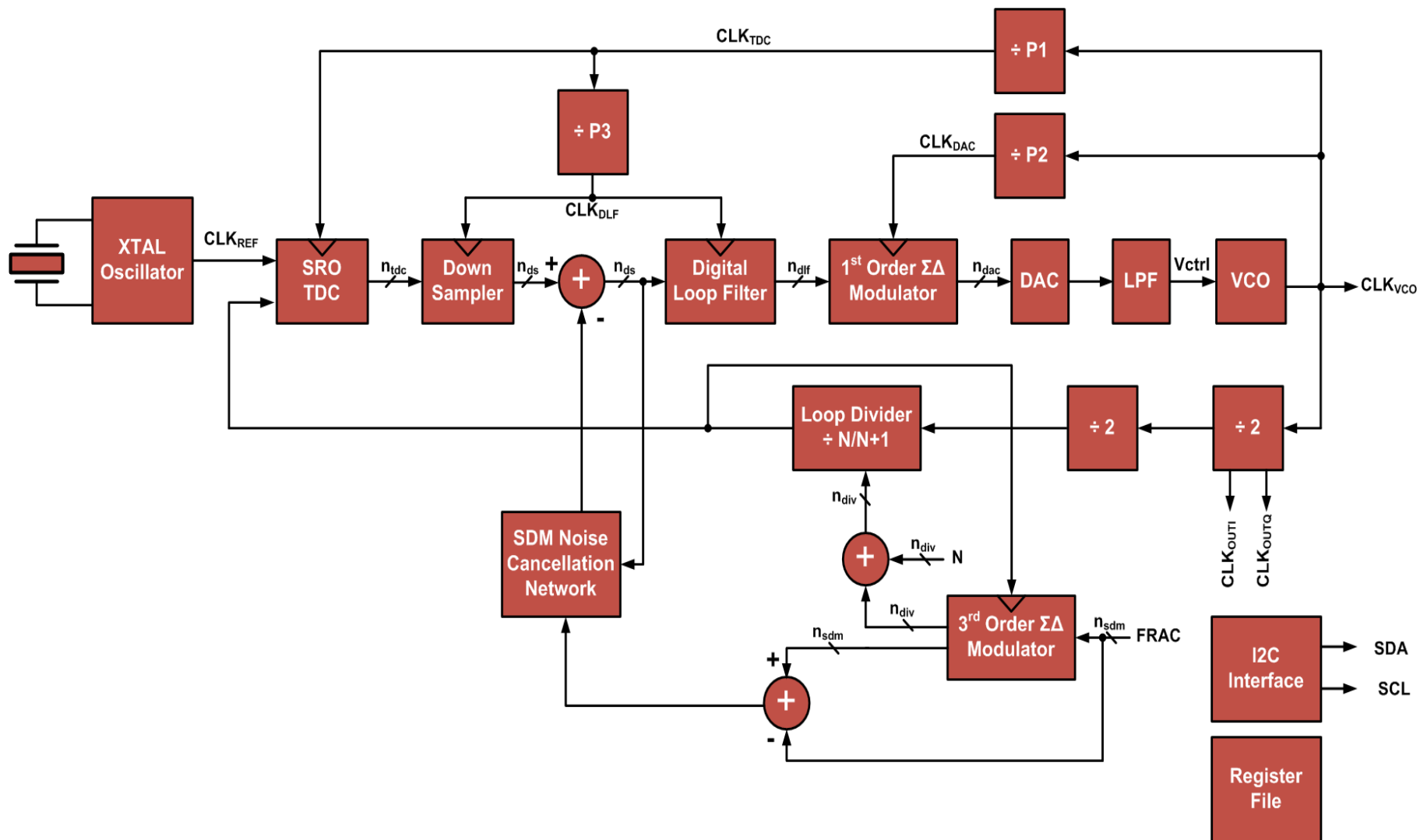
# All Digital Phase Locked Loop

## Digital Blocks

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March 2015

# System Block Diagram

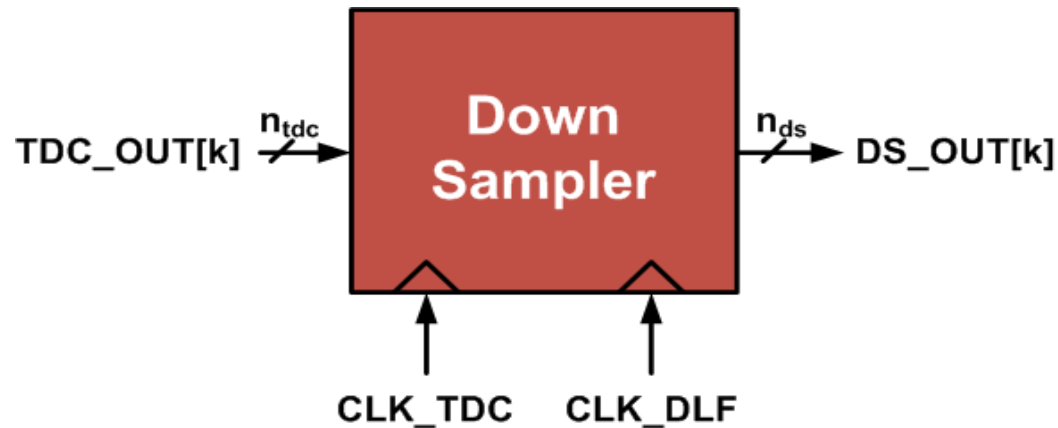


# Digital Blocks

- Down Sampler (CIC Filter)
- Digital Loop Filter
- MASH 1-1-1 Sigma Delta Modulator
- Sigma Delta Cancellation Network
- Register File
- SPI interface

# Down Sampler

# Block Diagram

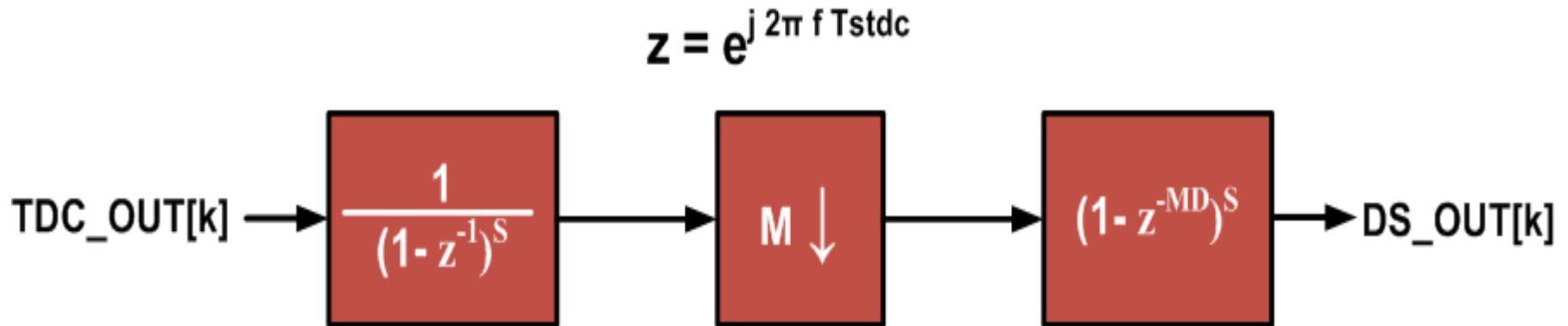


- Down Sampler is used to down sample the time-to-digital converter ( $TDC\_OUT$ ) output code from TDC sampling clock ( $CLK\_TDC$ ) rate to the digital loop filter clock ( $CLK\_DLF$ ) rate.
- The decimation factor of TDC is given by:

$$M = \frac{f_{sTDC}}{f_{sDLF}}$$

Where  $f_{sTDC}$ : TDC sampling frequency  
 $f_{sDLF}$ : DLF sampling frequency

# Transfer Function



- The Transfer function is given as:

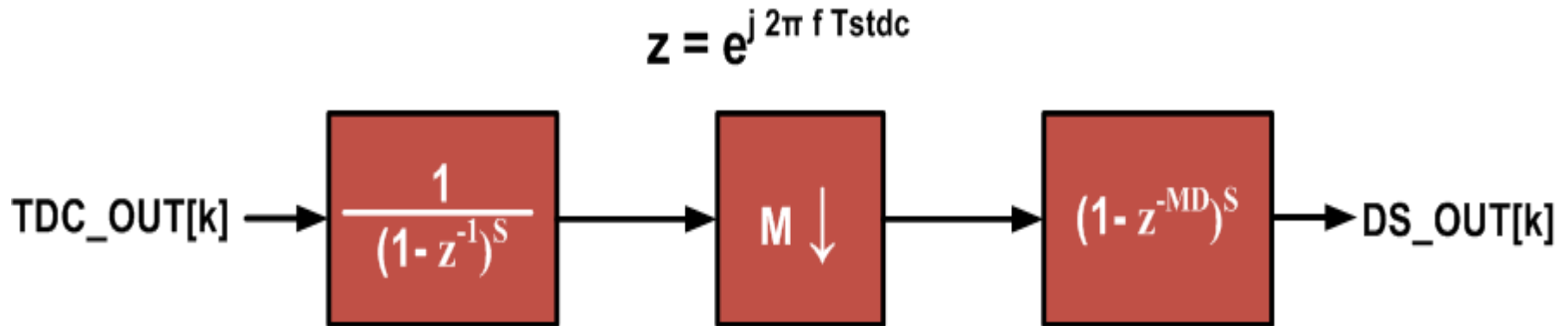
$$H(z) = \frac{(1 - z^{-MD})^S}{(1 - z^{-1})^S}$$

Where M: Decimation Factor

D: Number of Differential Delay Units

S: Number of CIC stages

# Transfer Function



- The bandwidth of this filter is given as:

$$f_{BW} = \frac{f_{sTDC}}{D M}$$

# Specifications

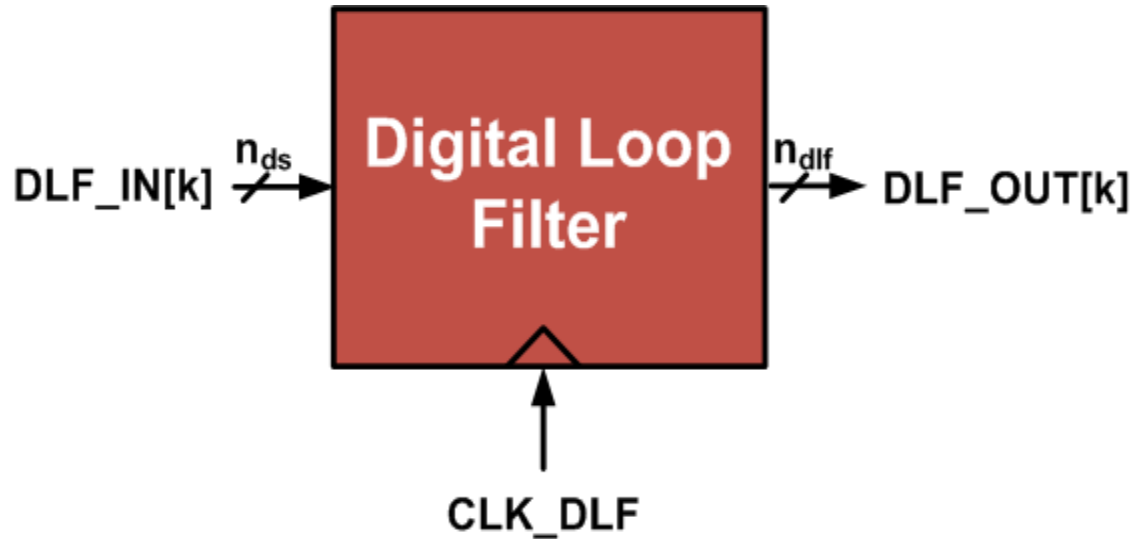
Design Parameter	Symbol	Min. Value	Typ. Value	Max. Value	Unit
TDC Sampling Frequency	$f_{\text{STDC}}$	600	-	625	MHz
DLF Sampling Frequency	$f_{\text{SDLF}}$	37.5	-	39.0625	MHz
CIC Filter Bandwidth	$f_{\text{BW}}$	-	19.53125	-	MHz
TDC Number of Output Bits	$n_{\text{tdc}}$	-	5	-	Bits
Down Sampling Factor	M	-	16	-	-
CIC Number of Stages	S	-	3	-	-
CIC Number of Differential Delay Units	D	-	2	-	-
CIC Number of Output Bits	$n_{\text{cic}}$	-	20	-	Bits
Down Sampler Number of Output Bits	$N_{\text{ds}}$	-	15	-	Bits

**Discard the last five least significant bits of CIC word to get the downsampler word**



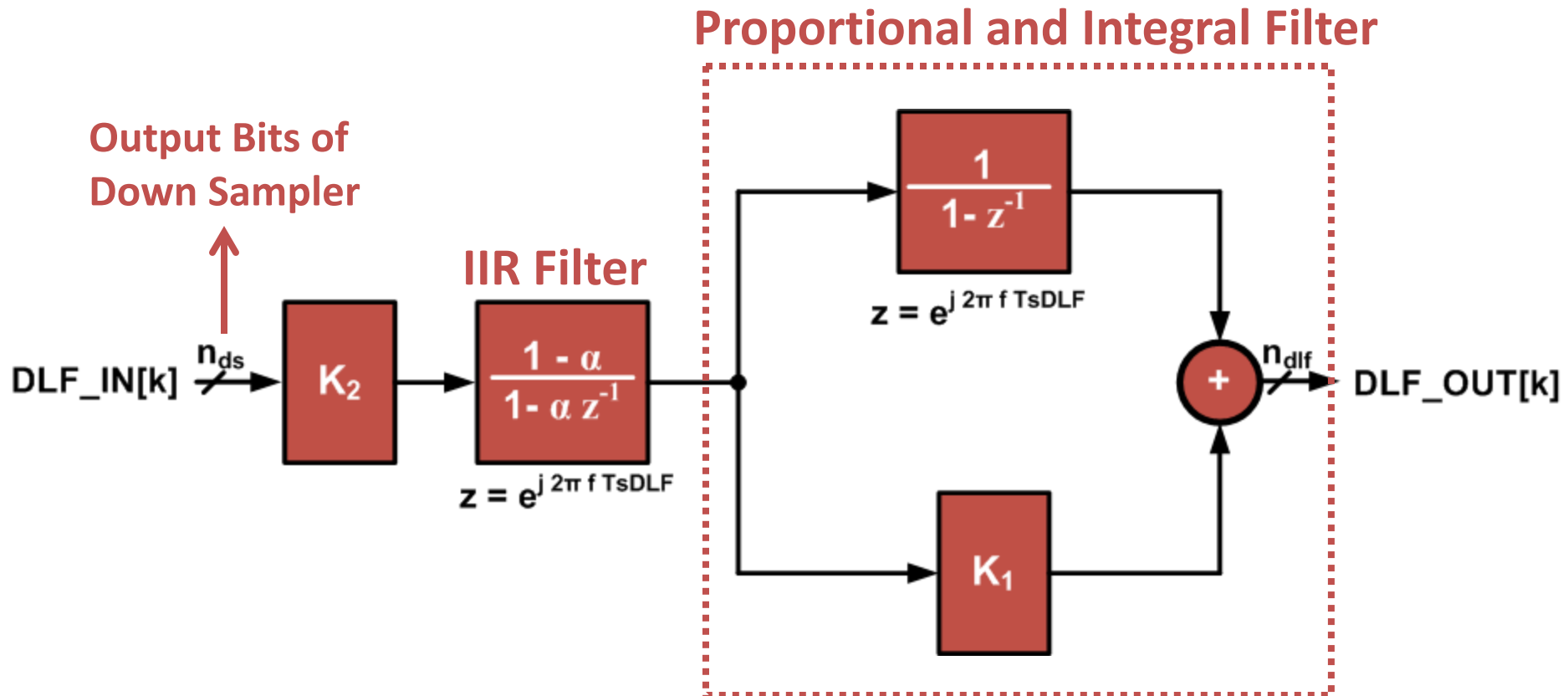
# Digital Loop Filter

# Block Diagram



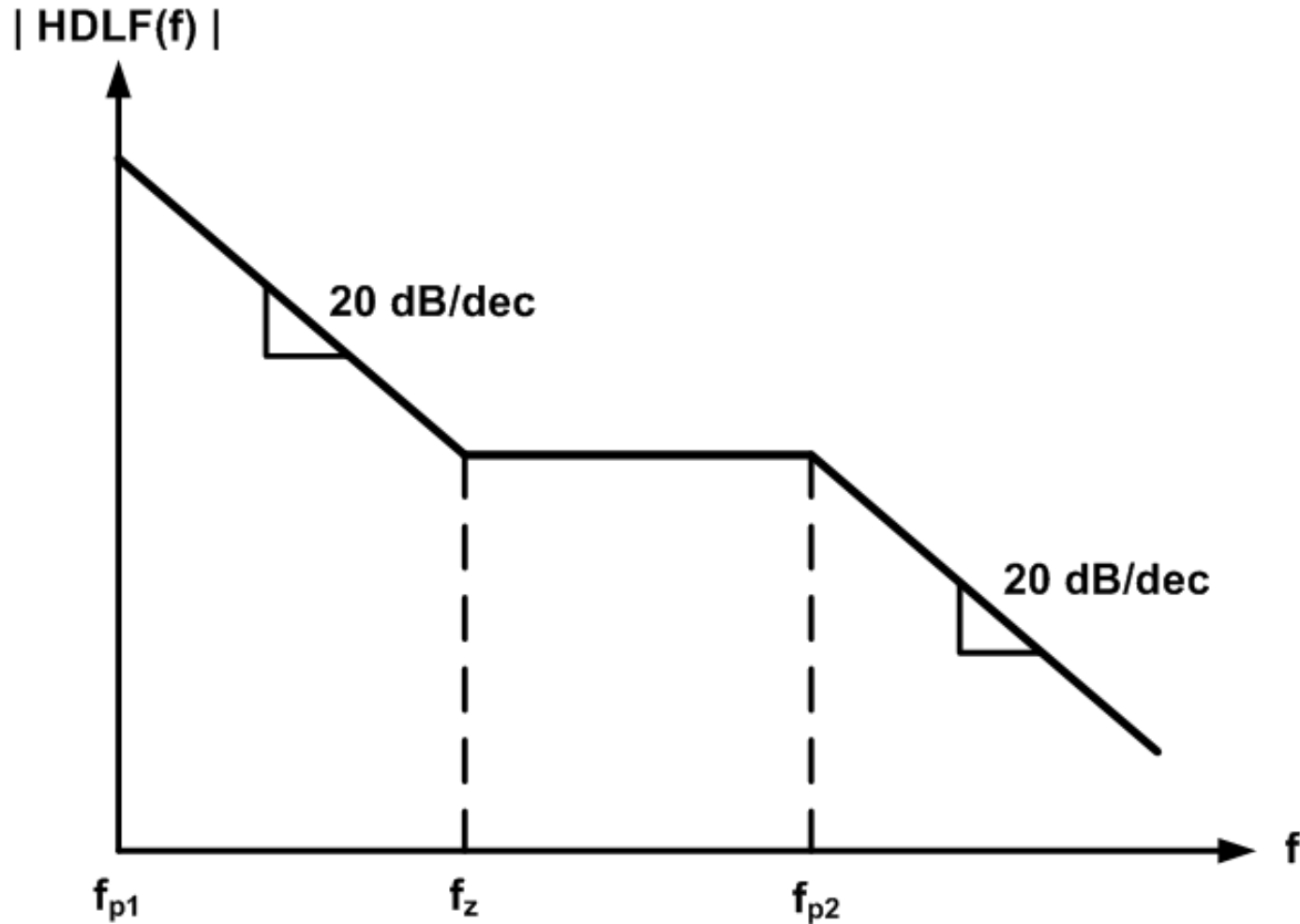
- Second-Order digital filter
- IIR Filter + Proportional and Integral Filter

# Transfer Function



$$H_{DLF}(z) = K_2 \times \frac{1 - \alpha}{1 - \alpha z^{-1}} \times \frac{(K_1 + 1) - K_1 z^{-1}}{1 - z^{-1}}$$

# Ideal Magnitude Response

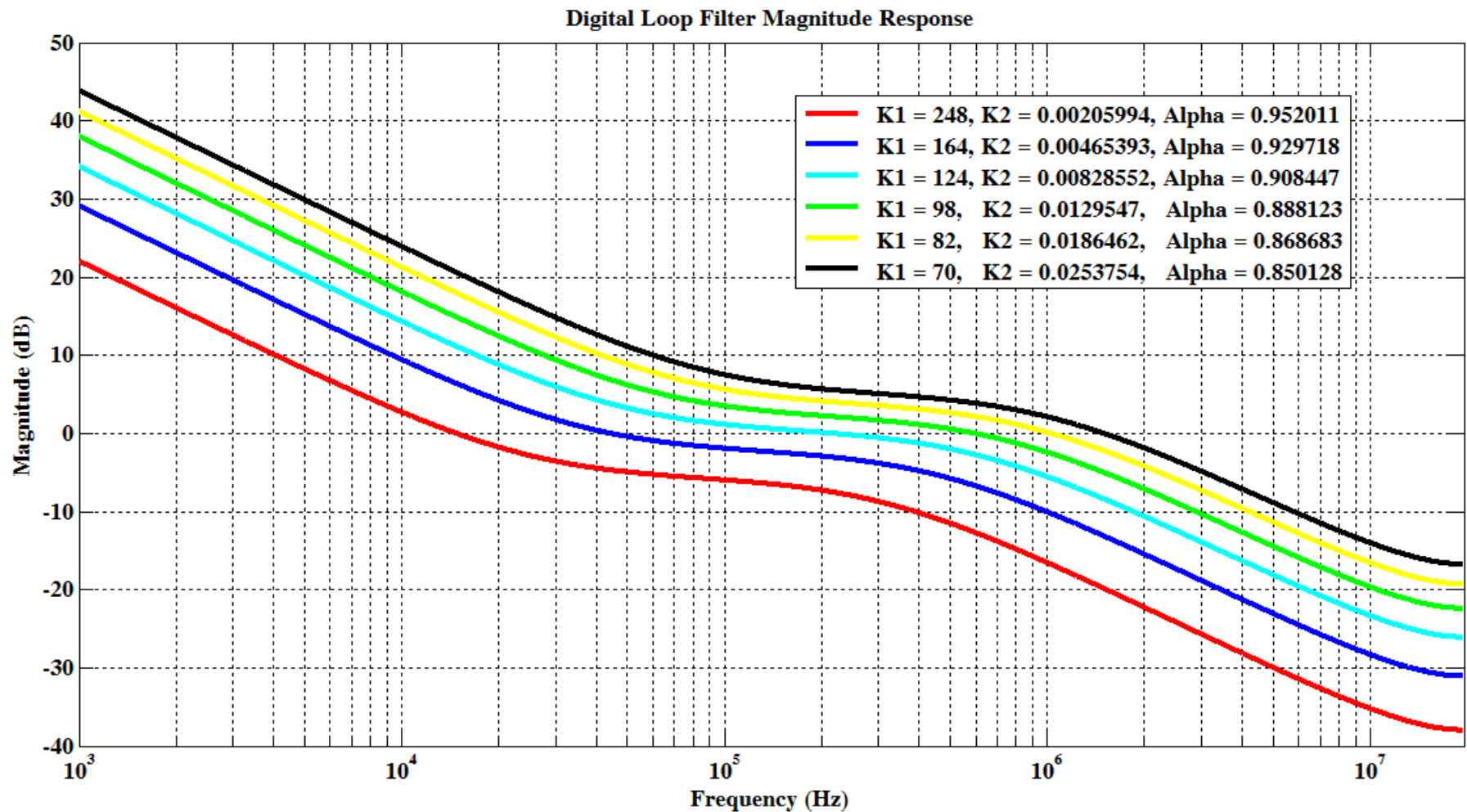


# Specifications

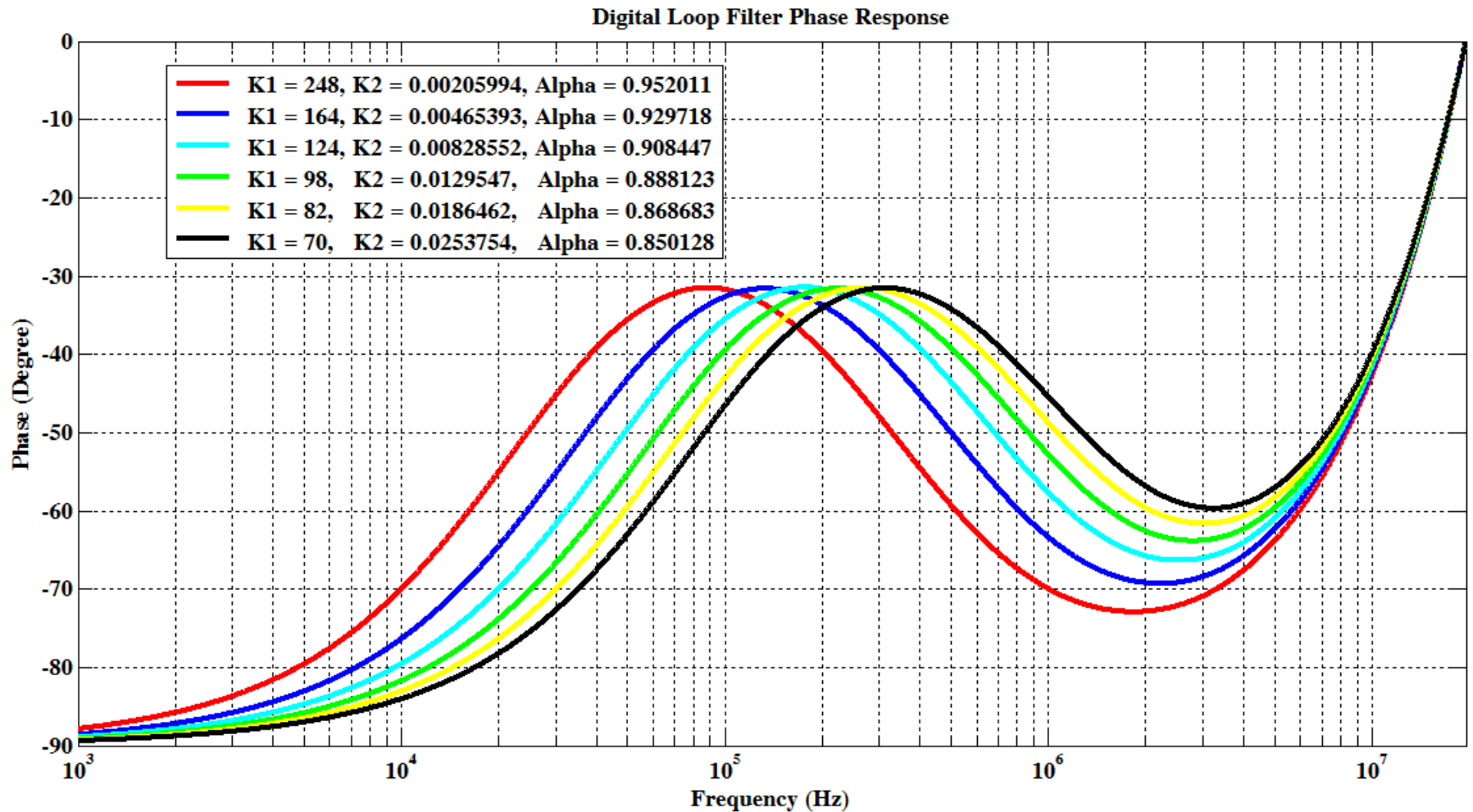
Design Parameter	Symbol	Min. Value	Max. Value	Unit
DLF Sampling Frequency	$f_{sDLF}$	37.5	39.0625	MHz
<b>Coefficients</b>	$K_1$	70	248	-
	$K_2$	0.00205994	0.0253754	-
	$\alpha$	0.850128	0.952011	-

- The DLF coefficients is needed to be programmable so it is need to be saved in the register file.

# Magnitude Response



# Phase Response



***Thank You!***