



VS IPL Signal Processing

By: Dr. Win Smith
General Manager/Chief Technical Officer
DNA Computing Solutions, Inc.
VS IPL Tutorial & User's Conference
February 27-28, 2002



VSIPL Signal Processing Functions

- **FFTs**
- **Convolution**
- **Correlation**
- **FIR Filtering**
- **IIR Filtering**
- **Windowing**
- **Miscellaneous**



FFTs in the VSIPPL

Function	Full VSIPPL	Core	Lite
Create FFT Object	1-D, 1-D Multiple, 2-D, 3-D	1-D, 1-D Multiple	1-D
Complex to Complex	1-D, 1-D Multiple, 2-D, 3-D	1-D, 1-D Multiple	1-D (*)
Complex to Real (***)	1-D, 1-D Multiple, 2-D, 3-D	1-D, 1-D Multiple	1-D
Real to Complex (**)	1-D, 1-D Multiple, 2-D, 3-D	1-D, 1-D Multiple	1-D
Destroy FFT Object	1-D, 1-D Multiple, 2-D, 3-D	1-D, 1-D Multiple	1-D
FFT Get Attributes	1-D, 1-D Multiple, 2-D, 3-D	1-D, 1-D Multiple	None

- * Out-of-Place Algorithm Only
- ** Forward Transform Only
- *** Inverse Transform Only



FFT Characteristics

- **Complex Calls Support Forward & Inverse Xform**
 - Including User Supplied Scaling
 - All Use Native Machine Floating Point Arithmetic
 - Complex-to-Complex Versions Can be In-Place or Out-of-Place
- **1-D Transforms Support Any Length N**
 - All Powers of 2 Must Have Order of $N \cdot \log(N)$ Operations
 - Order of $N \cdot \log(N)$ Operations Sustained with One Factor of 3 Included
 - Lengths Halfway between Powers-of-Two (i.e.. $64 \cdot 3 = 192$)
- **Multiple 1-D Transforms of Any Length N**
 - Block of 1-D Data Sets Sequentially 1-D FFT Transformed
- **2-D, 3-D Transforms Support Any Length $M \cdot N \cdot P$**
 - Separable Transform Executed in Each Dimension in Sequence
 - In Each Dimension:
 - All Powers of 2 Must Have Order of $N \cdot \log(N)$ Operations
 - Order of $N \cdot \log(N)$ Operations Sustained with One Factor of 3



Convolution in the VSIPL

Function	Full VSIPL	Core	Lite
Create Convolution Object	1-D, 2-D	1-D	None
Convolution	1-D, 2-D	1-D	None
Destroy Convolution Object	1-D, 2-D	1-D	None
Get Attributes	1-D, 2-D	1-D	None



Convolution Characteristics

- **1-D Real Input Data**
 - Any Data Length N
 - All Use Native Machine Floating Point Arithmetic
- **1-D Real Filter Kernels**
 - Kernel Length $M < \text{Data Length } N$
 - Variable Output Integer Decimation D ($D = 1$ Implies no Decimation)
 - D Normally 1 for Non-Low Pass Filters
 - Various Filter Symmetries
 - Non-Symmetric
 - Even Symmetric with Odd Length
 - Even Symmetric with Even Length
- **The Y Output Vector View Must Be of Length:**
 - Full: $(N + M - 2)/D + 1$,
 - Same: $(N-1)/D + 1$, or
 - Minimum: $(N - 1)/D - (M - 1)/D + 1$
- **2-D Convolution Constraints the Same as for 1-D Version**



Correlation in the VSIPL

Function	Full VSIPL	Core	Lite
Create Correlation Object	1-D, 2-D	1-D	None
Convolution	1-D, 2-D	1-D	None
Destroy Correlation Object	1-D, 2-D	1-D	None
Get Attributes	1-D, 2-D	1-D	None



Correlation Characteristics

- **1-D Real Input Data**
 - Any Data Length N
 - All Use Native Machine Floating Point Arithmetic
- **1-D Real Reference Vectors**
 - Pattern Length $M < \text{Data Length } N$
- **The Y Output Vector View Must Be of Length:**
 - Full: $N + M - 1$,
 - Same: N , or
 - Minimum: $N - M + 1$
- **2-D Convolution Constraints the Same as for 1-D Version**



FIR Filtering in the VSIPL

Function	Full VSIPL	Core	Lite
Create Decimated FIR Object	1-D	1-D	1-D
Decimated FIR	1-D	1-D	1-D
Destroy Decimated FIR Object	1-D	1-D	1-D
Get Attributes	1-D	1-D	1-D
Reset FIR Object to Initial State	1-D	1-D	1-D



FIR Filtering Characteristics

- **1-D Real Input Data**
 - Any Data Length N
 - All Use Native Machine Floating Point Arithmetic
 - Filtering Not Performed In-Place
- **1-D Real Filter Kernels**
 - Kernel Length $M < \text{Data Length } N$
 - Variable Output Integer Decimation D ($D = 1$ Implies no Decimation)
 - $1 \leq D \leq M$ ($D = 1$ for Non-Low Pass Filters)
 - Various Filter Symmetries
 - Non-Symmetric
 - Even Symmetric with Odd Length
 - Even Symmetric with Even Length
- **The Y Output Vector View Must Be of Length:**
 - N/D if $N \bmod (D) = 0$
 - $\text{INT}(N/D)$ Otherwise



IIR Filtering in the VSIPL

Function	Full VSIPL	Core	Lite
Create Cascaded IIR Object	1-D	1-D	None
Cascaded IIR	1-D	1-D	None
Destroy Cascaded IIR Object	1-D	1-D	None
Get Attributes	1-D	1-D	None
Reset IIR Object to Initial State	1-D	1-D	None



IIR Filtering Characteristics

- **1-D Real Input Data**
 - Input and Output Data Length $N \geq 2 * M$
 - All Use Native Machine Floating Point Arithmetic
 - Filtering Cannot Be Performed In-Place
- **M Cascaded Second Order Sections**
 - M x 3 Matrix for Real Numerator Coefficients
 - M x 2 Matrix for Real Denominator Coefficients



Windowing in the VSIPL

Function	Full VSIPL	Core	Lite
Create Blackman Window	1-D	1-D	None
Create Chebyshev Window	1-D	1-D	None
Create Hanning Window	1-D	1-D	None
Create Kaiser Window	1-D	1-D	None



Windowing Characteristics

- **Creates 4 Types of Weighting Vectors of Length N**
- **Blackman Window**
 - Using: + 0.42, - 0.5 and +0.08 Coefficients
- **Chebyshev Window**
 - Sidelobe Ripple Expressed in dB
- **Hanning Window**
 - Using Version with Non-Zero End Points
- **Kaiser Window**
 - Beta: Real Scalar, Transition Width Parameter



Miscellaneous VSIPL Functions

Function	Full VSIPL	Core	Lite
Histogram	1-D	1-D	1-D
Frequency Swap	1-D	None	None



Miscellaneous Function Characteristics

- **Histogram**
 - **Accept Real Input Vector of Length N**
 - 16-bit Integer or Native Machine Floating Point Format
 - **Create Output Vector of Length P (Number of Bins)**
 - Index from 0 to P - 1
 - Specify Threshold for Minimum Bin
 - Specify Threshold for Maximum Bin > Minimum Bin Threshold
 - Output May Be Accumulated Over Multiple Input Vectors
- **Frequency Swap**
 - **Accept Real Input Vector of Length N**
 - 16-bit Integer or Native Machine Floating Point Format
 - **Swap Halves of an N Element Vector to Re-map Zero Frequencies from the Origin to the Middle**



Summary

- **Rich Set of 1-D, 2-D & 3-D Signal Processing Calls**
 - **FFTs**
 - Forward/Inverse
 - In-Place & Out-of-Place Output Data Blocks
 - Complex-Complex, Complex-Real, Real-Complex
 - Optimized for: Powers-of-Two and One Factor of 3
 - **Convolution/FIR Filtering**
 - Various Decimation & Symmetry Options
 - **Correlation**
 - Variable Pattern Length
 - **Windowing**
 - Various Sidelobe Levels & Mainlobe Width Options
 - **IIR Filtering**
 - 2nd Order Building Blocks
 - **Histogram**