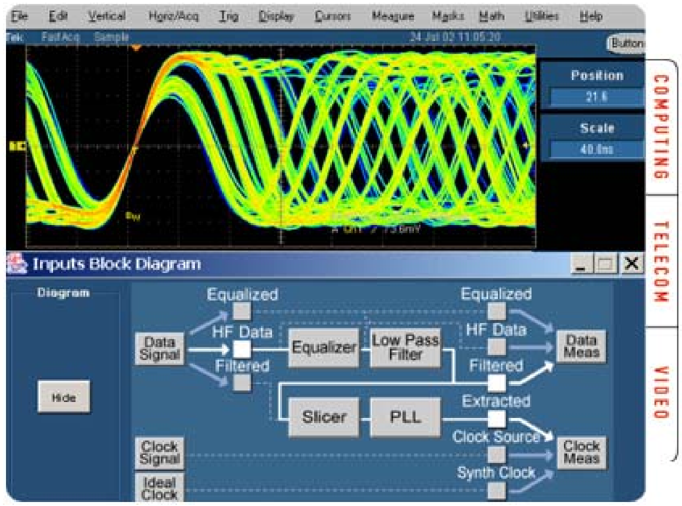
Using TekFlex™ to Test Optical Storage Designs Beyond Current DVD Standards



Engineers involved in the design and development of next-generation optical storage systems and chipsets need to continually stretch their designs beyond current (ECMA/ISO) standards. TDSDVD optical storage analysis and measurement software, coupled with a high-performance Tektronix oscilloscope, addresses this ever-increasing, complex need, allowing designers to optimize design performance quickly and efficiently.

Since the inception of the DVD standard in 1995, the growth and acceptance of this new technology has been phenomenal. No other entertainment format (including color television) has seen such overwhelming demand. Nevertheless, the need for higher capacity storage has increased exponentially. To meet this escalating demand newer and newer design innovations keep the DVD design-market-place bustling.

The emergence of many competing DVD standards has led to tremendous competition among companies and there is a scramble to develop the highest-capacity, maximum-performance drive, and be the first to market. The result: high time-to-market pressures. In addition, the developers working on next-generation DVD standards face the challenge to reduce costs. Chipset designers, on the other hand, though they work with existing standards, are under constant competitive pressure to add differentiators to their existing products.

These developers currently have no tool-set to test their designs for specifications beyond current ECMA (European Computer Manufacturers Association) standards. In the absence of the necessary tools, they face a daunting task that leads to delayed product introductions and increased cost of the final product.

An appropriate tool-set is critical to designers for quick, error-free, reliable testing to ensure that they introduce quality products in the least possible time.

This application note will focus on understanding and using TDSDVD software's unique TekFlex™ feature to test state-of-the-art optical storage designs beyond current ECMA/ISO standards.

Tektronix®
Enabling Innovation

Why Test Beyond Current Standards?

There is a tremendous demand from the market for increasingly higher amounts of storage capacity on a drive. This unmet market need has resulted in a scramble among the DVD companies to launch newer formats that provide higher disk storage and better performance. The pull from the market is so high that the optical storage industry has witnessed innovations in storage technologies leading to the doubling of capacity every nine months - twice the rate of Moore's Law.

Examples include Blu-ray Disc, which stores more than 20 G data, and MPEG-4 coding with Red-laser, multi-layered storage technology. In addition to these, many more standards are being unveiled with the sole aim of enhancing drive capacity and performance.

However, with this tremendous increase in drive capacity and performance, new levels of measurement challenges arise, faced by both next-generation DVD designers and chipset developers. There are no standard test tools that developers can use to test these upcoming standards.

Thankfully, the fundamental signal processing blocks of the DVD remains the same; see Figure 1. Most of the upcoming standards continue to use the Equalizer, Low Pass Filter (LPF), Slicer and Phase lock loop (PLL) blocks. Designers need to substitute or fine-tune these signal processing blocks (Equalizer, Low pass filter, Slicer and PLL) to maximize design performance.

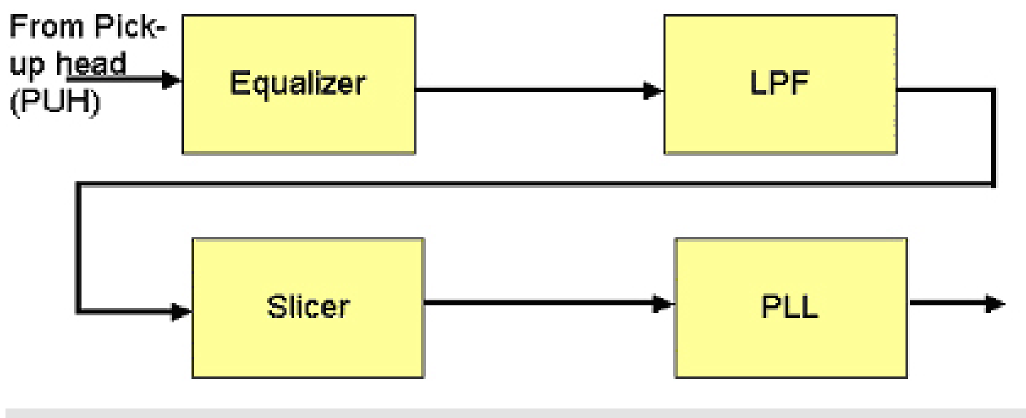


Figure 1. Signal Processing Architecture

Developers are currently using digital oscilloscopes to capture raw DVD (RF) data, or the outputs of the other processing blocks in Fig. 1. This data is then transferred to a PC that is running custom analysis and simulation tools. These custom tools, generally based on MATLAB or similar software tools, are developed in-house by these companies to test their state-of-the-art designs based on their own custom implementations of various signal processing blocks. The system-under-test is then analyzed based on these custom implementations. This is a highly crude and error-prone methodology that significantly affects time-to-market.

TekFlex Resolves Current Challenges

TDSDVD software's TekFlex feature enables designers to develop next-generation designs or optimize the performance of existing optical storage systems beyond current ECMA standards by allowing them to modify or substitute various signal-processing blocks with their custom implementation of these blocks.

The implementation of these processing blocks is dictated by various DVD standards, such as DVD-ROM. For example, the DVD-ROM format dictates/mandates that the Equalizer is a 3-tap transversal filter and the Low-pass filter is a 6^{th} order Bessel filter with a cut-off frequency of 8.2 MHz.

The figure below shows a case wherein the standard Low pass filter (6^{th} order Bessel) has been changed with a custom 4^{th} order Butterworth filter.

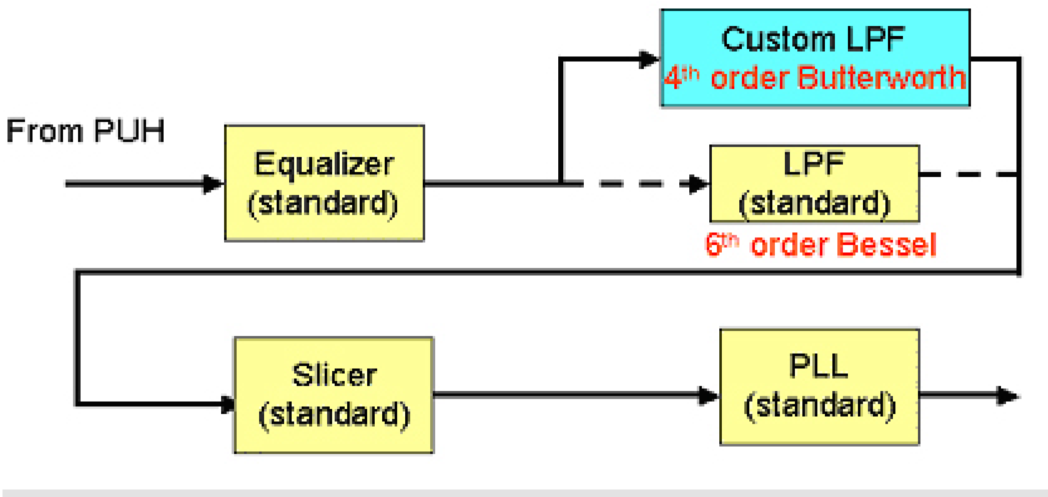


Figure 2. Custom implementation of LPF

The custom blocks usable with TekFlex are completely integrated with the TDSDVD application and no additional steps are required to run a configuration with this tool. The TDSDVD application executes the corresponding MATLAB or dll software component automatically, including opening MATLAB or loading the dll for the first run.

Note: MATLAB Version 6.1 or newer needs to be installed on the platform if you are using MATLAB .m files.

The figure below shows the Plug-in menu of the TDSDVD application. Users can select “Custom” and then browse to select their existing MATLAB .m files or .dll files for their custom implementation, using these existing files to make their measurements.

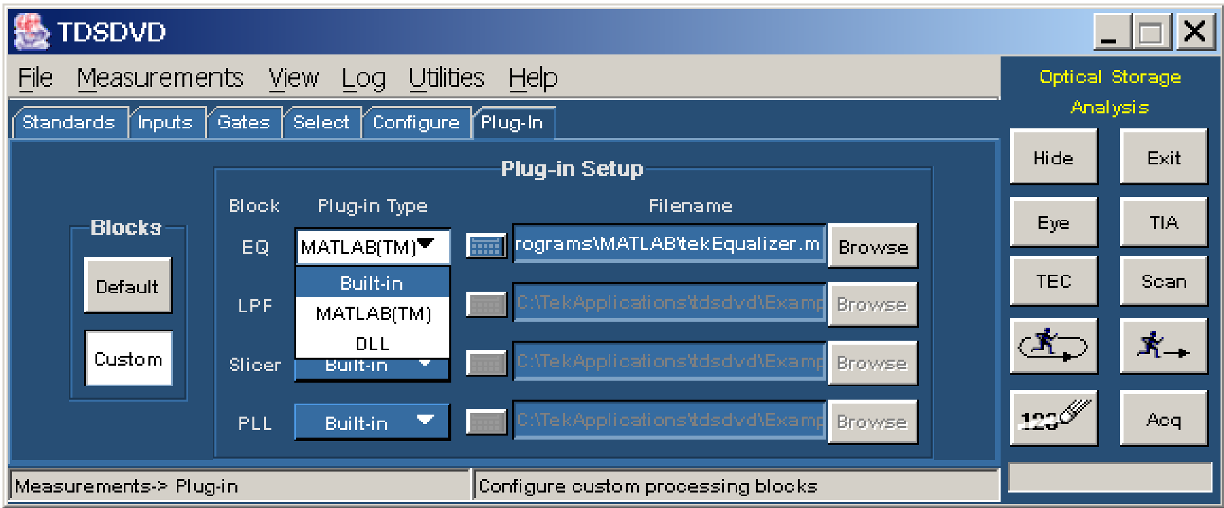


Figure 3. TDSDVD’s TekFlex Plug-in panel

Using TekFlex To Modify Standard Blocks For Custom and PRML Implementations

TDSDVD software comes with working source code examples for all four of the processing blocks for both MATLAB and dll.

In fact, the examples are more complex than would be necessary for the usual case. In order to make the MATLAB and dll examples produce exactly the same results as the built-in application code (which is Java implemented) the TekFlex examples have an additional step of calling a Java method.

The following MATLAB example illustrates a simple program that replaces the TDSDVD built-in low-pass filter (Bessel, 6th order) with a 4th-order Butterworth filter.

```
function y = tekLPF(u, sampleInterval, clockPeriod, cornerFrequency)

% tekLPF Tektronix MATLAB version of the DVD2 LPF.
% function y = tekLPF(u, sampleInterval, clockPeriod, cornerFrequency)
% This function implements the interface for substituting the default Tektronix DVD2 application
% LPF  with a user defined MATLAB plug-ins.
% The function tekLPF is executed if the user selects the MATLAB plug-in type for the
% DVD2 LPF block, and the TDSDVD application runs on a supported platform with access to a
% MATLAB % license (local or network).
% The input arguments are always of the following types (guaranteed by the calling
% TDSDVD software):
%   - u, the LPF input, is a 1xN  array (NUMERIC double)
%   - sampleInterval, the time difference between 2 consecutive samples of u [s], is
%     scalar (NUMERIC double)
%   - clockPeriod, the period of clock period of the waveform analyzed by the DVD2 application
%     [s], is a scalar (NUMERIC double)
%   - cornerFrequency, the user specified LPF corner frequency [Hz], is a scalar
%    (NUMERIC double)
% The output argument MUST BE of the following type for the DVD2 application to execute
% correctly.
```

```
%   - y, the LPF output, SHOULD BE a 1xN array (NUMERIC double)
%   Note: The "default" MATLAB NUMERIC type is double, and the MATLAB math
% operations return double scalars or arrays. Since the input arguments are doubles there is
% nothing special required to insure that y is of type double if no explicit casting is used in the
% DSP implementation of this function.

% The following line defines y to be of the correct type and size, 1xN (NUMERIC
% double), N = length(u).
y = zeros(size(u));
% This is the length of the vector y
N = length(y);

% INSERT USER CODE HERE: ANY CODE THAT WILL MODIFY THE VALUES OF y[i], i=1,N,
% WOULD WORK CORRECTLY.
% Save this file before modifying it to preserve a working version for this m file.

% All the next lines should be DELETED if the user inserts any code above this line!

% EXAMPLE CODE
runExampleJavaorMATLAB = 1;
if(runExampleJavaorMATLAB == 1)
   % This is the default Tektronix MATLAB behavior for this function and leverages the DVD2
   % Java implementation.
   % Make sure that the directory \tek\apps\dso\dvd\dsp exist in the same directory as this file,
   % and contains SlicerOutput.class and TekDSPLib.class
   % The default Tektronix Java equalizer implements a low-pass Bessel filter of order 6-th
   import tek.apps.dso.dvd.dsp.*;

   y = tek.apps.dso.dvd.dsp.TekDSPLib.calcLPFOutputDefault(u, sampleInterval,
  cornerFrequency, clockPeriod)';
else
   % Compute y as the output of a Butterworth filter based on input samples spaced at
   %  "sampleInterval" [s]
   % by
   %   - specifying a filter order
   %   - designing an analog Butterworth filter Ba(s)/Aa(s) with corner frequency
   %  "cornerFrequency" [Hz]
   %   - discretizing the Transfer Function (TF) to Ba(z)/Aa(z)
   %   - extracting the numerator and denominator (Bd and Ad) of the dTF from the discrete
   %  model
   %   - filtering the input with the designed discrete TF
   %   - gating the output y to the correct size required by the DVD application

   filterOrder = 4;
   [Bc,Ac] = butter(filterOrder, 2*pi*cornerFrequency,'s');
   TF_design = tf(Bc,Ac);
   dTF_design = c2d(TF_design, sampleInterval,'tustin');
   [Bd,Ad] = tfdata(dTF_design,'v')
   y = filter(Bd,Ad,u);
   y = y(1:N);
end;
```

Note: tekLPF is a part of the TDSDVD application and communicates to MATLAB.

Obviously, the implementation can be made much more computationally efficient by taking the filter design out of the loop and loading it from a (.mat) file in the above example. The above LPF MATLAB example illustrates that, as long as the user adheres to a simple input and output interface provided by the TDSDVD application, the software delivers extensive flexibility to implement user code.

To better understand the full capability that TekFlex delivers to solve a user's needs, we shall analyze a hypothetical alternative structure to Fig. 1, namely a maximum likelihood (ML) implementation. The same idea can be used for a PRML implementation.

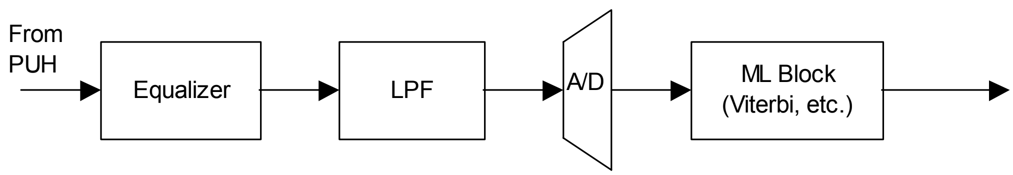


Figure 4. Hypothetical CD/DVD Processing Architecture

In the implementation in Figure 4, the Equalizer and the LPF are analog implementations, while the rest of the processing following the A/D converter is digital (such as FPGA).

It was previously mentioned that the architecture of the TekFlex feature provides great flexibility to the user as long as simple input and output interfaces are followed. In practical terms this can be used by a user to implement a different behavior for any of the DSP processing 4 blocks as long as the user is implementing the required interfaces for that of the block.

For instance, a user can inter-change the Equalizer and the LPF by inter-changing the code for each of the blocks when plug-ins are used for both blocks. Since this operation is transparent to the application the user has the task to interpret the waveform labeled EQZ as the output of the LPF block, and vice-versa.

Figure 5 shows how the architecture in Fig. 4 can be simulated using TDSDVD's TekFlex feature. This relies on the fact that the plug-ins can implement any desired behavior for a processing block regardless of its assigned name, in this case the LPF implementing the expected behavior and some additional processing.

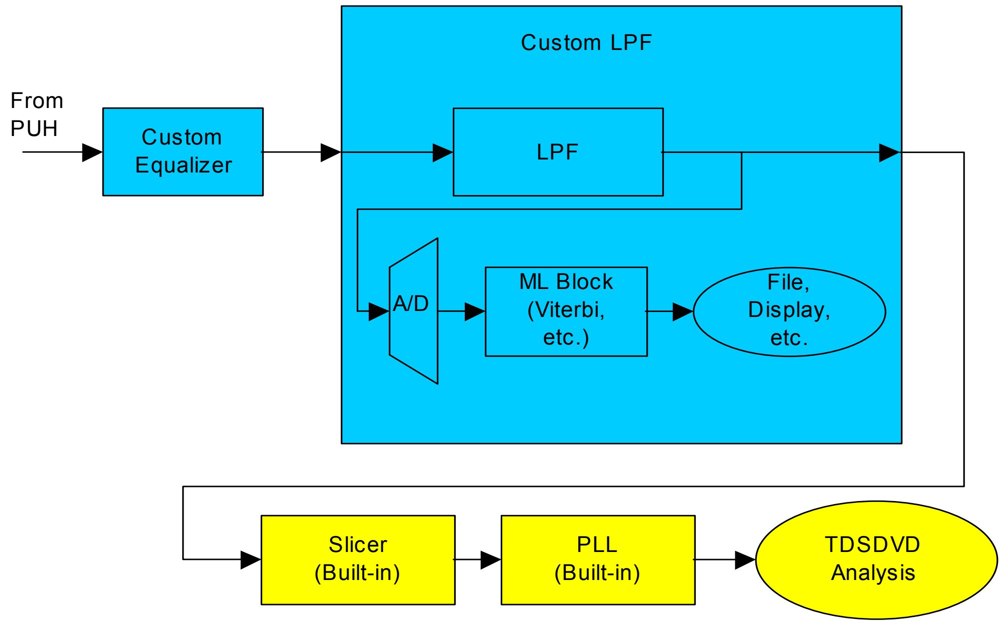


Figure 5. Using the TekFlex feature to address non-standard architectures

Figure 5 demonstrates how much flexibility the user actually has by exploring TekFlex's capabilities. The LPF block was used to produce a custom LPF output (necessary for the next block), but at the same time to also simulate an alternative architecture. Since the input of the ML processing signal path depends on the output of the LPF, the ML processing structure can also be implemented inside the block labeled Slicer.

An implementation such as the one in Fig. 3 allows the user not only the flexibility in easily exploring various architectures in a familiar and productive environment, but also offers comparisons of those implementations with the built-in, standard-specified architectures.

Note: The signal from the PUH is already the output of the A/D in the TDS oscilloscope running TDSDVD. However, it still makes sense to simulate customer block processing implementation like the ones in Fig. 4 since the A/D of the TDS oscilloscope has superb sampling rate and resolution performance compared to the A/D needed in the customer implementation. The custom Equalizer and LPF are simulated in double precision, which further improve on the 8-bit resolution of the PUH signal, at a sample rate that could be in tens of giga samples per second. As a result, a TekFlex practical implementation like in Fig. 5 could easily and accurately simulate (in software) a customer A/D of up to 6-7 bits, at hundreds of mega samples per second.

The example presented in Figure 5 offers just one of many possible implementations in solving one problem. The extent to which TekFlex can solve other problems is limited only by the user's imagination.

Conclusion

To meet the ever-growing demand of storage capacity and maximum performance on optical drives, companies are constantly unveiling new architectures. These state-of-the-art designs present new challenges that the developer must resolve.

With its unique TekFlex feature, TDSDVD software (paired with a high-performance Tektronix oscilloscope), allows developers to quickly and accurately test their state-of-the-art designs. This tool-set provides superior performance with unparalleled ease-of-use, making it an ideal solution for optical storage designers.

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