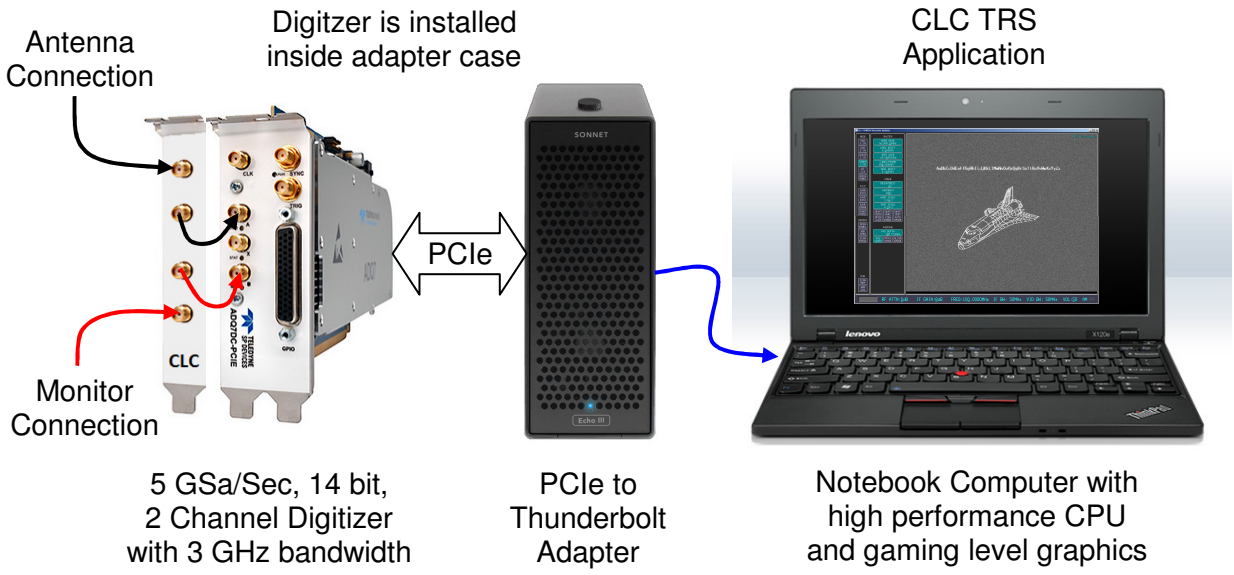
TRS-ADQ7-PCIe Preliminary Datasheet

The Complete TEMPEST Detection System That Fits in a Backpack

The TRS ADQ7-PCIe is a digital TEMPEST Receiver System that uses Commercial-Off-The-Self (COTS) components. The use of COTS[1] components allows high performance at a lower cost and with easier maintenance. The system is based on a notebook computer[2] and a SP Devices ADQ7DC digitizer in the PCIe form factor. The PCIe card is installed in a Thunderbolt-3 adapter that connects to the notebook computer. Firmware in the digitizer and software running on the computer provides all of the TEMPEST detection system functions. Calibrated measurements can be taken directly from the integrated oscilloscope. The result is a complete[3] TEMPEST detection system in a small form factor[4].

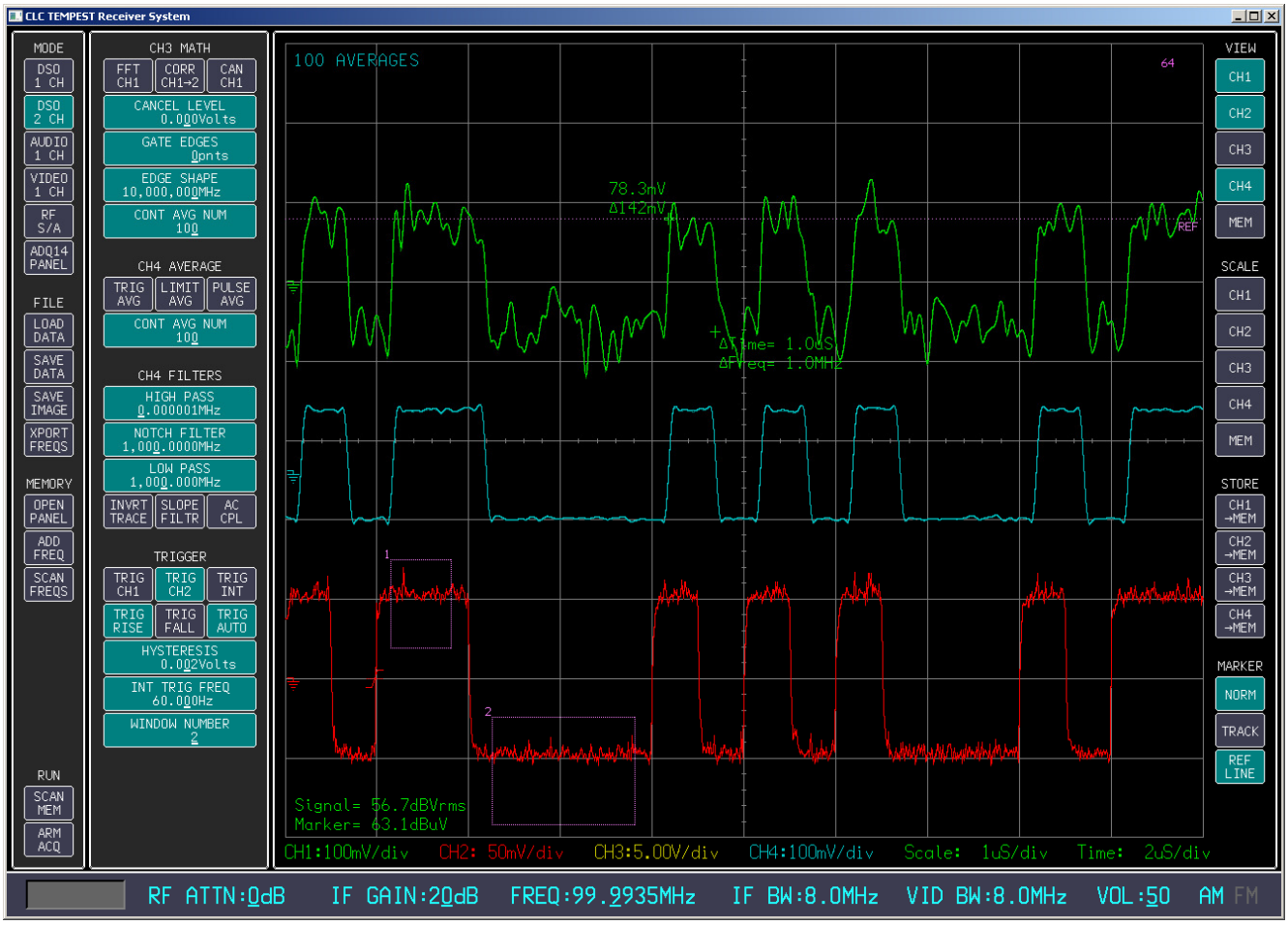


An interface card assembled from COTS parts sits above the third PCIe slot in the Thunderbolt adapter and provides the Low Noise Amplifiers (LNAs) and attenuators that feed the digitizer inputs. The SP Devices firmware then digitizes the signals and provides a high performance I/Q digital down converter and decimation. The digitized data is transferred over the PCIe bus in the adapter and then to the computer over the Thunderbolt cable. The TEMPEST Receiver System (TRS) software processes the data using multiple CPU cores and the Graphics Processing Unit (GPU). The software then displays the RF spectrum, demodulated signal, and the monitor signal in different views or modes. The modes include:

- Digital oscilloscope displaying demodulated RF and monitor signals for correlation.
- Audio spectrum analyzer for audio voice analysis of the demodulated RF signal.
- Video raster image for video analysis of the demodulated RF signal.
- RF spectrum analyzer.

The TRS in Oscilloscope Mode

The TRS can seamlessly switch between modes, allowing the search for signals using the integrated oscilloscope and then quickly switching to an audio or video analysis mode. The image below illustrates the use of windows to trigger on a repetitive pattern for signal averaging while searching in DSO mode. Note that the receiver controls at the bottom of the application window are always in view.

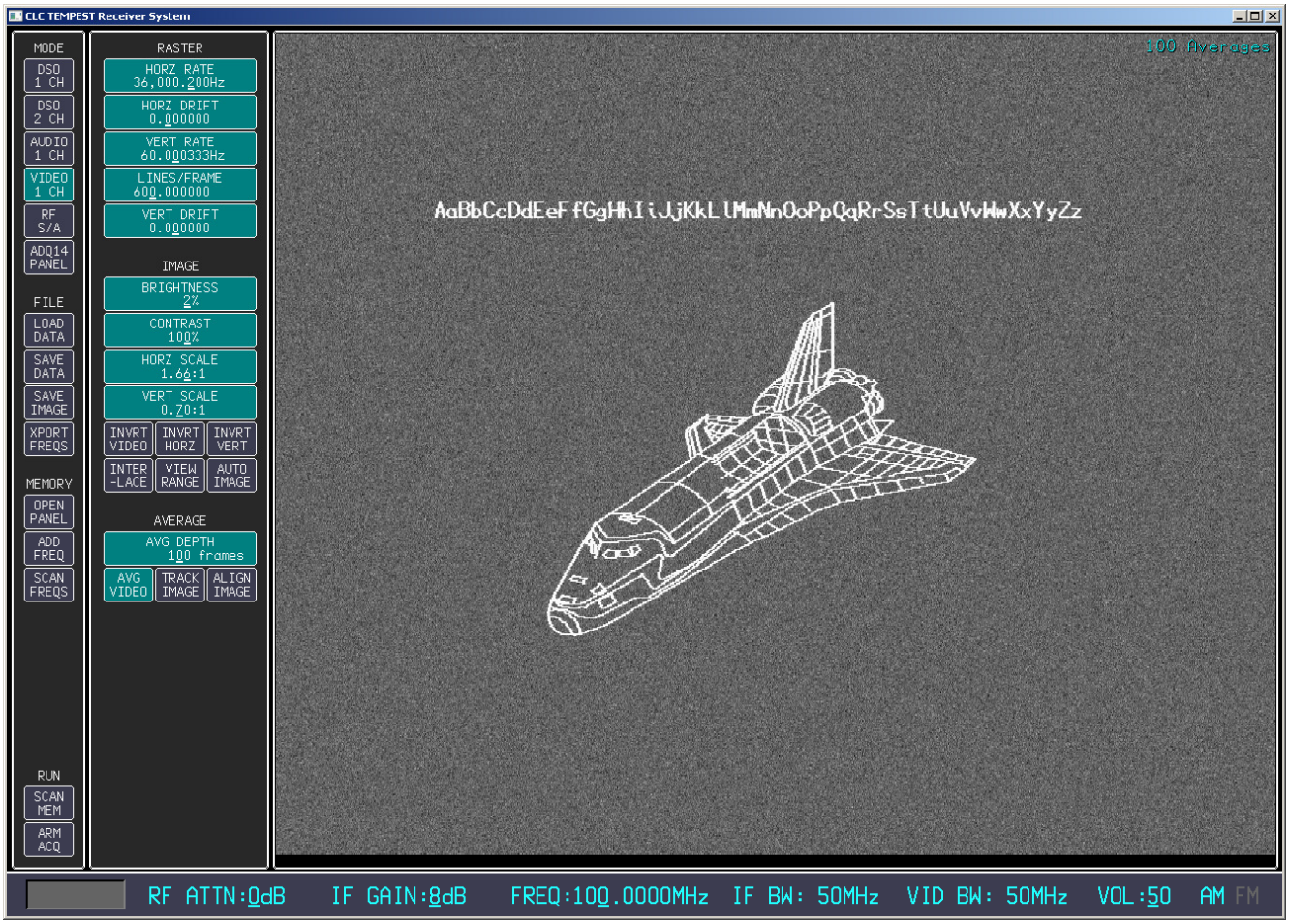


When running live, the traces provide persistence for visual correlation. The demodulated green trace also displays the range of values for signals represented by one pixel on the display. This allows the detection of fast signals in slow time bases that can be missed by conventional digital oscilloscopes.

The true RMS signal level and calibrated signal level between the markers is displayed in the bottom left corner of the oscilloscope virtual CRT. The true RMS value allows for measurements of the Detection System Sensitivity (DSS). The calibrated signal level allows signal measurement without the use of a substitution source. One button press saves the configuration and signal level measurement for inclusion into a report.

The TRS in Video Mode

The Video mode displays a raster video image. Three acquisition types let you view live video with continuous averaging, view a deep-average of stored video, or visually average live or stored video. The system provides advanced averaging and imaging functions to reduce noise and enhance video content. The system can display live video at bandwidths up to 125 MHz.

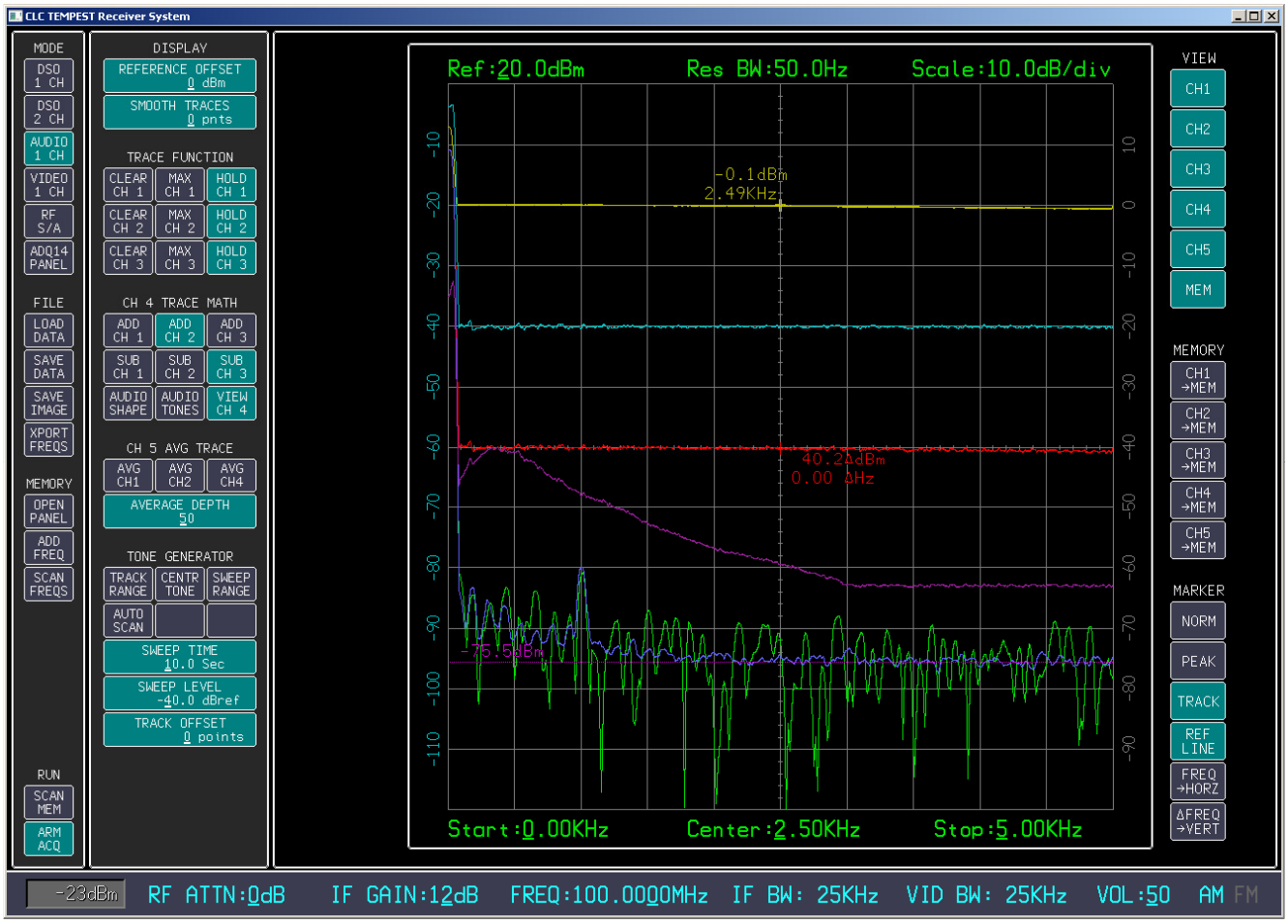


The application window can resized to fit the size of display used. The spectrum analyzer, oscilloscope and image windows are resized to the application window size. This allows better resolution when a high resolution computer display is used. The video image can also be dragged and zoomed using the mouse to provide better detail of any part of the video image.

Inverted video, inverted images, and interlace controls allow for the display of different video standards. Advanced averaging and frame stabilization using the GPU processing provides real time and post processing capabilities.

The TRS in Audio Mode

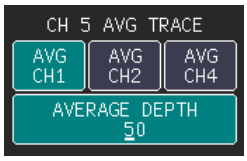
The Audio mode displays an audio spectrum analyzer with controls similar to a conventional analog spectrum analyzer. The image below displays an example crosstalk test for AM audio on a carrier. The yellow trace is the reference trace using the integrated tone generator. The RED trace is the crosstalk trace. The attenuation between the two is displayed as the blue trace, which has a separate scale showing the -40dB level. The violet trace is the spectrum of voice that can be used for the analysis of voice signals. The blue trace is the average of the green noise trace. The receiver and audio spectrum analyzer have high dynamic range. As in this example, the range is usually limited by source.



Graphical controls are used for the oscilloscope and the spectrum analyzers. The traces and markers can be dragged and expanded using the mouse. Markers are can also be used to automatically track the selected signal or find the peak and minimum value of the traces.

An Auto Scan mode is provided to automatically control the tracking generator and trace acquisition to provide a audio quick scan. When performing crosstalk test on multiple carriers, a Scan Freqs mode is used to find an active carrier that has been saved in memory.

Keep It Simple (KIS) Graphical User Interface



The system is operated with a mouse using simple controls that are always in view in the application window. Simply position the mouse pointer over a control and scroll the mouse wheel to change the value. The horizontal mouse scroll (or wheel tilt) selects the digit that is controlled.

Above are the receiver controls. Simplified controls that are always in view provide foolproof operation. The controls can be operated with the mouse or shuttle jog. For users who prefer hands-on controls, an X-Touch Mini USB MIDI controller can be added so that each receiver control can be operated with physical knobs.

Tuning can be performed with a shuttle/jog, the mouse, the keyboard, or continuously with the mouse side-buttons. The tuning rate can be by the digit or by a ratio of the IF bandwidth. Five different rates can be selected with the keyboard function keys or with the shuttle/jog buttons.

Easy Upgrades and Maintenance

Because the system is based on software instead of hardware and firmware, it is easy to provide regular upgrades. Users can also request enhancements to meet their requirements. Most software upgrades and enhancements are provided at no cost. There is no software installation required except for the instrument drivers. Simply copy the TRS software to the destination folder, replacing any older versions.

Because the TRS is a complete system, calibration is not required for the signal generators or oscilloscopes associated with standard analog receivers. An automated DSS and calibration can be performed with an optional Wind Freak signal generator.

Because the system is an assembly of COTS components[5], repair can be performed by any professional technician using the open source schematics. There are no printed circuit boards to replace.

Options

Contact the vendor for a description of these available options:

- Frequency converter to extend the receiver tuning range to 10 GHz.
- Frequency pre-selector to reduce out of band carriers
- Automated DSS and calibration verification.
- Installation in a desktop computer for higher performance[6].

APPLICATION CAPABILITIES

Compatibility	• MS-Windows 7 and later
Window size	• Four window sizes with scaled fonts to match display. • Scaled DSO and video image to match window size
Configuration memory	• Last configuration saved and recalled at next startup. • 30 configurations saved in memory and data files. • Separate pop-up panel for memory control . • Find and select active carrier from saved configuration.
User interface	• KIS (Keep It Simple) graphical user interface with all controls for the user mode (view) on screen.
User input devices	• Advanced mouse and any combination of Contour Shuttle/Jog, X-Touch Midi controller, and/or keyboard.
Modes	• 2 Channel, 5 trace DSO mode • 1 Channel, 6 trace Audio Spectrum Analyzer • 1 Channel video raster image display • 1 Channel, 6 trace RF Spectrum Analyzer • ADQ7DC instrument status and configuration
Files	• Last configuration file (saved & recalled automatically). • Data file containing configuration and acquired demodulated data for post-processing. • Video, DSO CRT, and Spectrum Analyzer CRT images saved in Bitmap format.
Processing	• 64-bit multi-threaded architecture using up to the number of CPU cores available • Processing in single GPU using OpenCL

ACQUISITION CAPABILITIES

Streaming Mode (automatically selected)	• 2 channel oscilloscope at bandwidths up to 60 MHz • Continuous audio at bandwidths up to 125 MHz • Continuous video raster at bandwidths up to 125 MHz
Record Mode (automatically selected)	• 2 channel oscilloscope mode up to 500 MHz • RF Spectrum Analyzer up to 2 GHz • No audio, no video raster
Memory Mode	• Displays previously acquired demodulated signal and Channel 2 (if in DSO mode) from FIFO memory

RECEIVER CAPABILITIES

RF input	• 2.5 dB noise figure typical[7] • 5 dBm maximum input level (failure)[8] • -20 dBm maximum input level at saturation • Separate frequency pre-selector is optional.
Frequency range	• 10 KHz to 2 GHz • 2 GHz to 10 GHz with optional frequency converter
Frequency resolution	• <2 Hz in streaming mode • <1 KHz in record mode (bandwidths > 60 or 125 MHz)
Frequency conversion	• Direct digital conversion to baseband
IF bandwidth	• 1 KHz to 500 MHz any value using direct entry control. • 1 KHz to 500 MHz in 10 bandwidths per decade using scroll control.
Post demodulation (video) bandwidth	• 1 KHz or IF Bandwidth/200 up to the IF bandwidth.
RF attenuation	• 0 to 30 dB in 1 dB steps[9]
IF gain	• Emulated (mathematical) gain from 0 to 60 dB
Demodulation modes	• Direct AM (I/Q vector magnitude) • Narrowband FM (I/Q differentiated phase) • PM and wideband FM to be determined
Audio Output	• One channel of computer audio in stream mode • No audio available in record mode (<60 MHz bandwidth) • Volume control by application and MS-Windows

OPTIONAL FREQUENCY CONVERTER CAPABILITIES

RF input	• 2.8 dB noise figure typical • 8 dBm continuous/23 dBm peak maximum input level.
Frequency range	• 2 GHz to 10 GHz tunable • Heterodyne conversion to 2 GHz IF
Frequency resolution	• <2 Hz in streaming mode • <1 KHz in record mode (bandwidths > 60 MHz)

DSO MODE CAPABILITIES

Timebase	• 5 mSec/div to 10nSec/div in 1-2-5 sequence or any value in range by direct entry. • Expanded timebase from main timebase/10 to main timebase/2.
Trigger	• Rise or fall edge of CH1 or CH2 • Up to 8 trigger requirements based on windows • Selectable frequency (based on sampling clock) • External (to be determined). • Selectable hysteresis
Input Channels	• CH1: Demodulated RF signal (Channel A of digitizer) • CH2: Baseband monitor signal (Channel B of digitizer)
Processed Channels	• CH3: FFT, signal correlation, and noise pulse reduction with continuous averaging • CH4: Advanced signal averaging of CH1 based on threshold, range limit and pulse detection. • Ch4: High pass, low pass and notch filters. • CH5: Memory of CH1 to Ch4 for reference
Trace range	• CH1, Ch2 and Ch3: 10 mVolt to 5 volt/div • Ch4: 10 µVolt to 5 volt/div
Resolution	• Source resolution: 14 bit. • Processed resolution: Float precision. • Pixel resolution: based on display and window size.
Graphical CRT functions	• Positioning and scaling of all traces • Expanded timebase scroll with highlighted traces • Delay and level position of trigger and trigger windows • Positioning of cursors and reference level line
Marker Functions	• Amplitude level and time of main cursor • Delta level and time between cursors with corresponding frequency • Track or move to peak of selected trace
Trace memory	• Last 100 traces stored in memory. • Tab forward, tab backward and delete trace

VIDEO MODE CAPABILITIES

Raster Rates	• Horizontal rate: 15 KHz to 200 KHz, 1 mHz resolution. • Vertical rate: 25 Hz to 600 Hz, 1 milli-Hz resolution. • Vertical line rate: 200 to 4000 lines, 0.0001 resolution • Horizontal drift control for sub pixel/finer resolution • Vertical drift control for non-integer number of lines • Rates can be set from Audio Spectrum Analyzer
Image Controls	• Brightness and contrast. • Horizontal scale ratio from 0.1 to 10.0. • Vertical scale ratio from 0.5 to 10.0. • Automatic horizontal scale, brightness and contrast. • Invert horizontal, vertical and image (negative). • Interlace (analog television format)
Averaging	• Sub pixel averaging in all modes • Continuous averaging with selectable depth and image drift stabilization. • Summed averaging of demodulated signal memory with selectable depth • Post processing image alignment.
Resolution	• Source resolution: 14 bit. • Processed resolution: Float precision. • Pixel resolution: based on display and window size. • 8 bits of displayed intensity resolution (grayscale),
Graphical CRT Functions	• Image zoom with mouse wheel. • Image Position. • Horizontal frame alignment.

AUDIO SPECTRUM ANALYZER MODE CAPABILITIES

Frequency Range	• 0 to 20 KHz for audio in 10 horizontal divisions. • 200 KHz for video horizontal capture.
Resolution Bandwidth	• 3.1 Hz to 200 Hz in binary steps
Amplitude (Referenced to receiver output level)	• Selectable scale in 1-2-5-10-20 sequence, 12 vertical divisions • 50 dBm to -50 dBm reference level • Separate reference for CH4 Math trace • Selectable reference offset • Selectable trace smoothing, 0 to 50 points
Resolution	• Source resolution: 14 bit. • Processed resolution: Float precision • Pixel resolution: 800 by 680
Base Channels 1, 2, 3	• Source: Demodulated signal • Modes: Clear/write, maximize or, hold
Math Channel 4	• Source: Sum of positive or negative values of CH1, CH2, and/or CH3, all combinations. • Filter with voice spectrum or STC contour curve • Mark trace with voice spectrum or STC frequencies
Average Channel 5	• Source: CH1, CH2 or CH4. • Continuous averaging with selectable depth.
Memory Channel 6	• Source: CH1 though CH5. • Displayed as reference.
Graphical CRT Functions	• Positioning of cursors and reference level line • Position of band-pass and notch filter frequencies • Frequency zoom with mouse wheel. • Reference level via trace position. • Separate reference/position for CH4 Math trace
Marker Functions	• Amplitude level and frequency of main cursor • Delta level and frequency between cursors • Separate trace sources for main and delta markers • Track or move to peak/valley of selected channels • Tab to next or previous voice or STC frequency

AUDIO SPECTRUM ANAYZER OUTPUT CAPABILITIES

Output	• Left channel of computer audio
Frequency Range[10]	• Track Range: Continuous from 0 to 20 KHz. • Sweep Range: Continuous from 0 to 20 KHz • Center Tone: Center frequency up to 20 KHz
Amplitude	• 0 to -100 dB referenced to computer audio level.
Sweep Time	• 1 to 100 seconds
Track Function	• Maximizes only at current frequency • Selectable delay between output and receiver input
Auto Scan Function	• Step 1: Disables audio output and clears traces • Step 2: Maximizes noise on CH1 trace and holds • Enables Sweep Range audio output, • Maximizes signal on CH2 trace and holds

RF SPECTRUM ANALYZER MODE CAPABILITIES

Frequency Range	• 0 to 2GHz in 10 horizontal divisions.
Resolution Bandwidth	• To be determined
Amplitude	• Selectable scale in 1-2-5-10-20 sequence, 12 vertical divisions • 50 dBm to -50dBm reference level • Separate reference for CH4 Math trace • Selectable reference offset
Resolution	• Source resolution: 14 bit. • Processed resolution: Float precision • Pixel resolution: 800 by 680
Base Channels 1, 2, 3	• Source: Demodulated signal • Modes: Clear/write, maximize or, hold
Math Channel 4	• Source: Sum of positive or negative values of CH1, CH2, and/or CH3, all combinations.
Average Channel 5	• Source: CH1, CH2 or CH4. • Continuous averaging with selectable depth.
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Marker Functions	• Amplitude level and frequency of main cursor • Delta level and frequency between cursors • Separate trace sources for main and delta markers • Track or move to peak/valley of selected channels

IMPORTANT INFORMATION

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For more information, please contact
CLC TEMPEST Solutions
codycrawford@clcTEMPESTsolutions.com
858-335-4947
D-U-N-S: 080716998
CAGE Code: 8G4F8

[1] For the TRS, COTS is defined as having no printed circuit boards or special order parts. The assembled parts require the connection of power lines between the components and the PCIe power supply. Some of these are soldered connections and cable taps.
[2] A high performance GPU is required. It is recommended that the computer be purchased as a part of the system in order to achieve the performance described by this datasheet.
[3] The term "complete TEMPEST system" does not include transducers, such antennas or probes, or cables to connect to the transducers..
[4] A rack mounted case is also available for the Thunderbolt adapter, which will not fit in a backpack.
[5] There is no guarantee that the COTS parts will always be available. The schematic provides critical specifications for the parts that can be used to find compatible replacements if the original part is not available.
[6] A by placing the PCIe digitizer and interface in desktop computer, continuous audio and video can be provided at higher bandwidths. However, the form factor is larger and a computer display and keyboard are required.
[7] The sensitivity is based on the typical Noise Figure specification provided by the LNA manufacturer and varies with frequency. The actual Noise Figure value may be slightly higher due to the connections to the LNA.
[8] A more robust LNA with a 13 dBm maximum input level may be substituted at no additional cost. The Noise Figure increases to 3 dB at 10 KHz and to 4 dB at 2 GHz.
[9] The attenuation is after the LNA and is used to prevent saturation of the digitizer input. To prevent saturation of the LNA from high level signals, the attenuator may be placed before the LNA with a 1 dB decrease in the input sensitivity.
[10] The minimum and maximum frequency is limited by the computer audio capability