EECL

www.eecl.co.uk

Dual Channel Converter

User Manual

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Product Overview

EECL's Dual-Channel Frequency Converter is a highly integrated and flexible solution designed for frequency conversion, supporting both up conversion and down conversion. The module has an IF range of 100 MHz to 8 GHz and an RF range of 8 to 32 GHz.

With ultra-low phase noise, a tunable local oscillator, adjustable gain, and built-in image and LO rejection filtering, it provides a compact, single-module solution suitable for a wide variety of applications. The module has integrated thermal management to stabilize gain drift with temperature and the module can be integrated into our rack mounted switch matrix if required.

Key Features

The EECL Dual-Channel DC-32GHz Frequency Converter is a highly integrated, bi-directional solution designed for versatile up- and down-conversion up to the Ka-Band. At its core, the system features two independent channels driven by a built-in, shared Local Oscillator (LO) with 1 MHz step resolution, ensuring exceptional phase-coherency ideal for demanding applications like radar and 5G/6G research. The unit delivers superior signal fidelity through ultra-low phase noise, exceptional channel isolation (>90dB) achieved via proprietary shielding techniques, and robust integrated spur, image, and LO rejection filters (>80dBc). Furthermore, the converter offers a highly flexible 60dB variable gain control range, internal oven-based temperature stabilization for near zero drift, and seamless remote operation via multiple software interfaces, making it an exceptionally adaptable and high-performance tool for both laboratory testing and automated rack environments.

Target Applications

The EECL Dual-Channel Frequency Converter is a highly versatile instrument designed to support a wide array of mainstream RF, microwave, and telecommunications applications. One of its most prominent use cases is serving as a highly cost-effective VNA frequency extender. By pairing this converter with a standard, lower-frequency Vector Network Analyzer, laboratories can perform high-fidelity Ka-Band S-parameter (S21) measurements and comprehensive antenna anechoic chamber characterizations without the prohibitive expense of a dedicated high-frequency VNA. In the telecommunications sector, the unit acts as a crucial building block for 5G and 6G research and development, enabling the seamless up- and down-conversion of complex, wideband modulated signals. Furthermore, its strictly phase-coherent, shared-LO architecture makes it an ideal analog front-end for radar system development, phased-array testing, and general automated production testing. Whether integrated into a high-volume manufacturing rack or used as a flexible daily tool on the lab bench, the converter provides engineers with premium microwave capabilities and exceptional signal purity across a multitude of testing environments.

Safety and Handling

The unit is a low voltage and low power RF device. There are no specific safety requirements associated with its use. The maximum power the unit is capable of generating is +10dBm.

Electrostatic Discharge (ESD) Sensitivity

Although the module has on board ESD protection, the unit should still be considered as ESD sensitive. Use protection where possible and avoid touching the RF connector pins and any other connector pin.

Maximum RF Input Power Limits

The unit should not be subjected to input power beyond +16dBm on its RF ports. Use beyond this may cause damage of the unit.

Unpacking and Installation

Box Contents

The unit is shipped in a heavy-duty rugged transit case. Inside the module is shipped using ESD protected bags and accessories are provided (USB-C to USB-A) cable, (USB-C to USB-C) cable and power adapter.

Physical Dimensions and Rack Integration

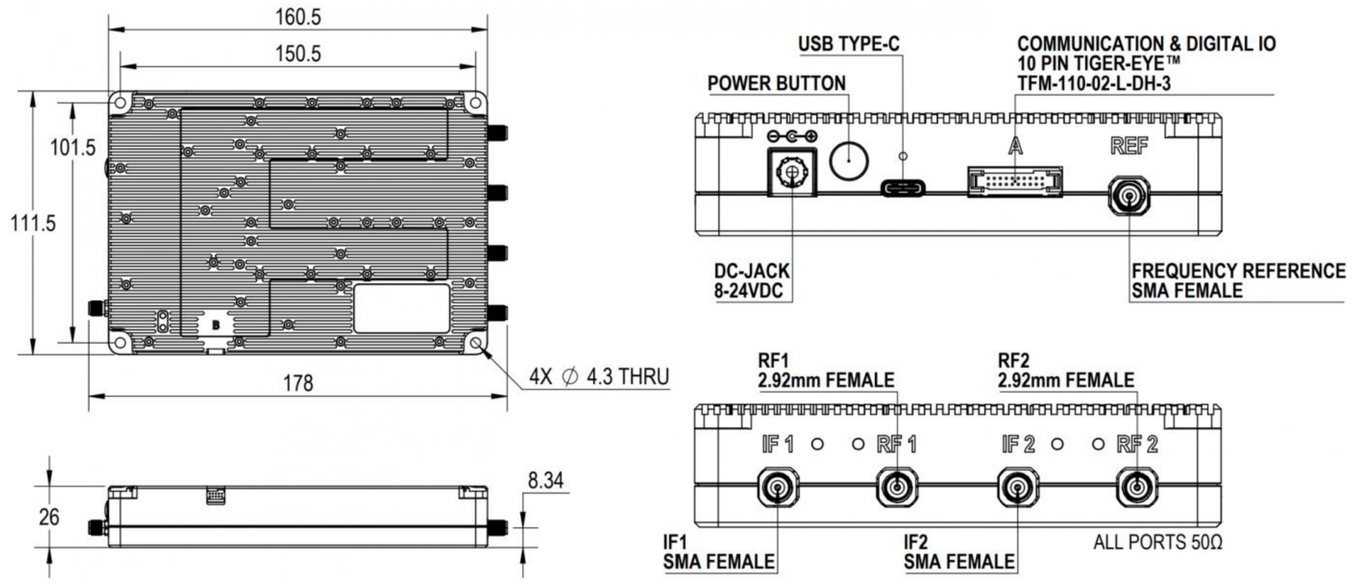


Figure 1: Physical dimensions

Powering Up

Connect the provided power adapter to the module and plug in. The units LEDs should come on. Take the USB cable and connect the USB-C port to the PC using either USB-A cable or USB-C cable. The operating system should install the FTDI driver and enable a virtual comport to connect to the device. The unit is then ready to use.

Hardware Overview & Interfaces

Front Panel Layout and Indicators

The front panel is shown in Figure 2. It consists of channel 1 IF and RF connectors and channel 2 IF and RF connectors. Each RF port has an LED light next to it to signify its status.

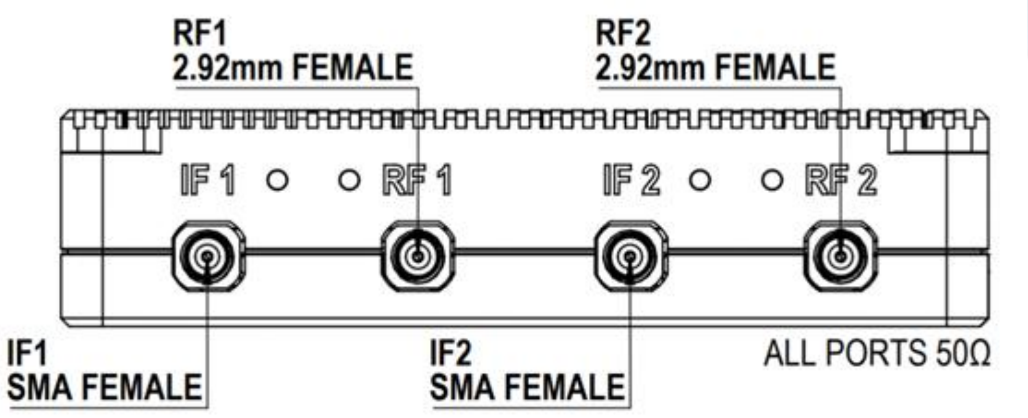


Figure 2: Front panel connectors

Rear Panel Connections

The rear panel consists of the following connections

DC power input jack (8 to 24 volts). The DC input feeds a DCDC converter so the current demands increase as the input voltage is reduced. At 12V the unit consumes around 1Amp of current.

Button, this can be used for various features that can be implemented in software. Currently it initiates a power on and off of the unit.

USB Type-C, this connector serves as power input when the DC jack is not used and provided the communication interface.

The 10 pin connector allows the unit to control external devices, provide triggering signals and allows us to drive external equipment.,

The reference connector can be set as input / output / disabled and supports 100MHz frequency locking.

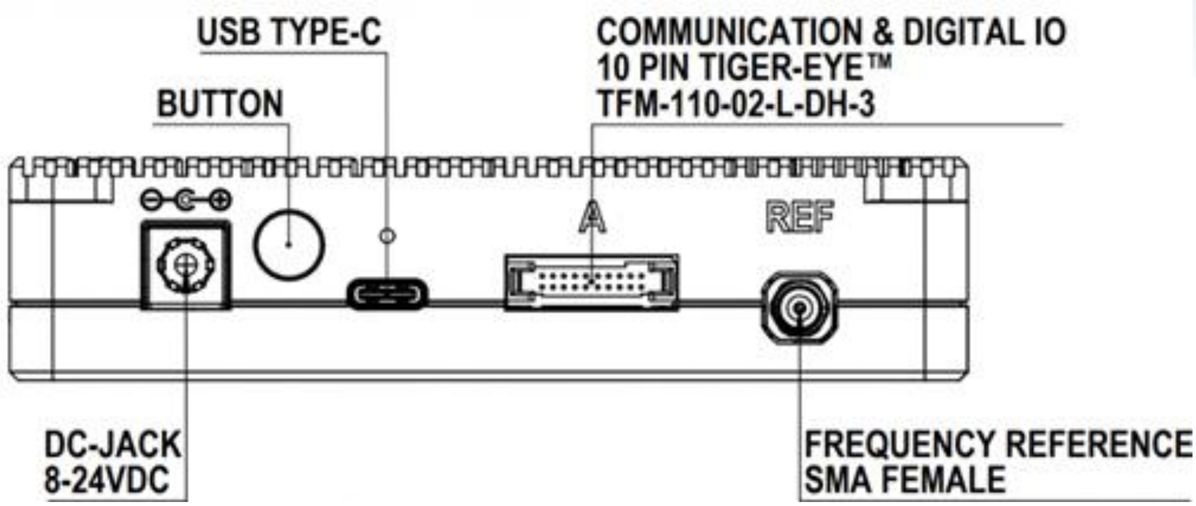


Figure 3: Rear panel connectors

System Architecture & Theory of Operation

System Block Diagram Overview

Figure 4 illustrates the functional block diagram of the system. While this schematic is a simplified representation of the internal architecture, it accurately reflects the user-facing signal flow and operational logic. In practice, to seamlessly cover the full frequency spectrum, the hardware dynamically switches between multiple RF paths and mixer stages.

At the core of the module is a master synthesizer that drives the dual RF conversion chains. Both channels are meticulously engineered to be perfectly matched in phase, path length, insertion loss, and overall performance. Despite sharing a common Local Oscillator (LO) to ensure strict phase coherency, the two channels are heavily shielded to provide exceptional internal isolation with negligible cross-coupling. This architecture allows each channel to be configured and operated entirely independently, functioning as a dedicated up- or down-converter as required by the user.

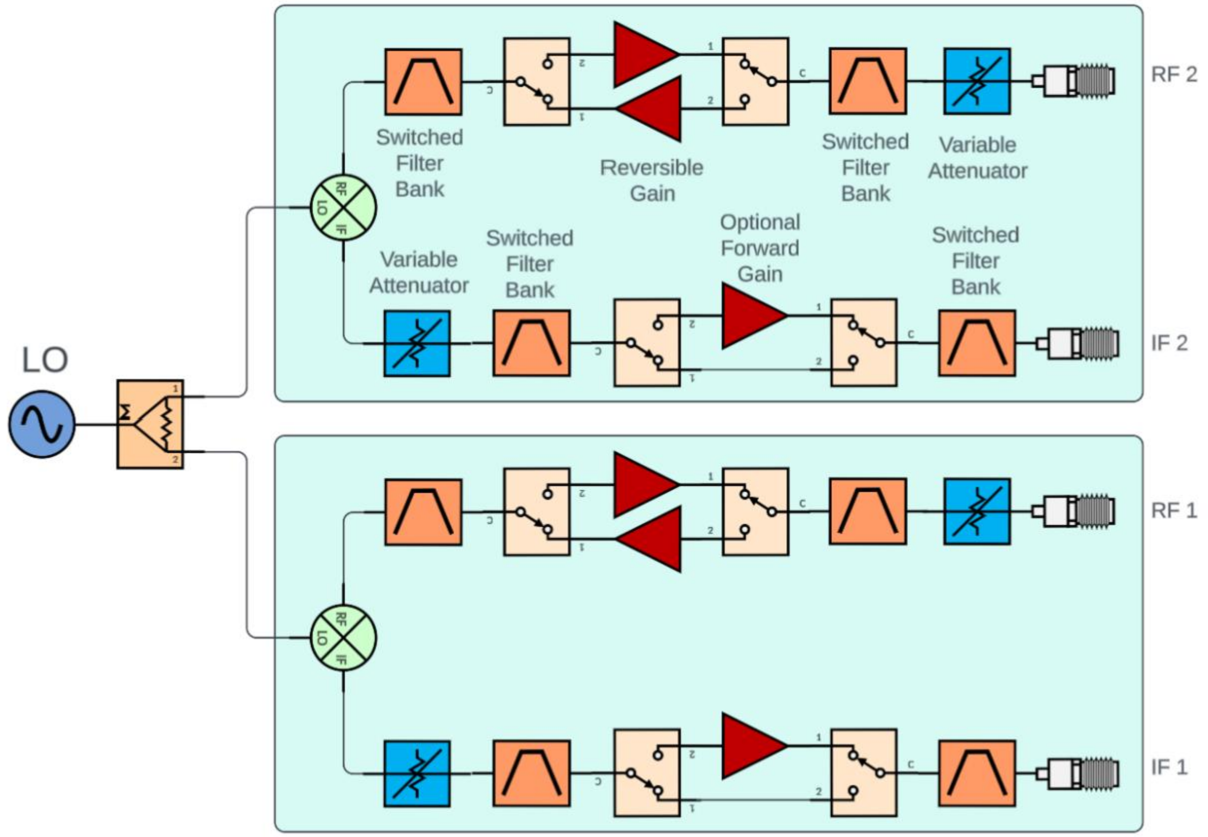


Figure 4: System Block Diagram

Shared Local Oscillator (LO) and Phase-Coherent Conversion

Phase-Coherent Architecture: The system utilizes a single Phase-Locked Loop (PLL) synthesizer to generate the Local Oscillator (LO) signal for both frequency conversion chains. By splitting this ultra-low phase noise output symmetrically between the two channels, the system ensures perfect frequency and phase synchronization with absolute zero drift between the two arms. This inherently phase-coherent topology makes the module highly effective for precision applications, allowing it to function seamlessly as a VNA frequency extender, a radar test system, or a high-performance communication front-end.

Tuning and Spectral Optimization : The integrated synthesizer is highly versatile and can be programmed in 1 MHz steps. It supports both integer and fractional-N operating modes. While fractional mode provides fine frequency resolution, it can naturally introduce more spurious emissions (spurs) into the signal chain. For optimal spectral purity and maximum spur reduction, it is highly recommended to operate the LO in integer mode. This is achieved by selecting an LO frequency that is an exact multiple of 100 MHz (e.g., 16,000 MHz, 16,100 MHz, 16,200 MHz, etc.).

Clock Reference and Synchronization To maintain strict timing accuracy, the synthesizer is inherently locked to an onboard, ultra-low phase noise 100 MHz internal reference clock. For integration into broader test setups, the unit's reference port is highly configurable:

Internal Reference Output: The port can output the internal 100 MHz signal to synchronize external laboratory equipment to the converter.

External Reference Input: The port can accept a user-supplied external reference clock to lock the converter to an existing master laboratory clock.

Note: If your system architecture relies on a standard 10 MHz reference rather than 100 MHz, EECL offers a dedicated companion module capable of seamless bi-directional conversion between 10 MHz and 100 MHz. Please contact us for more information on integrating this accessory.

Independent Up-Conversion and Down-Conversion Paths

Channel Independence and Directionality The module features two entirely independent RF/IF conversion chains. Users can individually configure each channel for either up-conversion or down-conversion, with independent control over attenuation, gain, and filter settings. However, because both chains are driven by a split signal from the master synthesizer, they inherently share the same Local Oscillator (LO) frequency.

Front-Panel LED Indicators To provide clear, at-a-glance status verification, the module uses intuitive front-panel LEDs to indicate the active output port for a given configuration:

- **Up-Conversion Active:** The **RF LED** illuminates, indicating that the IF port is the input and the RF port is the output.
- **Down-Conversion Active:** The **IF LED** illuminates, indicating that the RF port is the input and the IF port is the output.

IF Chain Architecture

- **Up-Conversion (IF Input):** During up-conversion, the IF chain applies no forward gain. This design assumes the IF input signal is sourced from standard laboratory equipment with a naturally high Signal-to-Noise Ratio (SNR). For optimal performance, it is recommended to keep the IF input power between **-30 dBm and 0 dBm**.
- **Down-Conversion (IF Output):** When acting as a down-converter, the IF chain engages an internal amplifier to provide approximately **20 dB of forward gain**.
- **Glitch-Free Fine Gain Control:** The IF chain features a Voltage Variable Attenuator (VVA) offering a 30 dB continuous adjustment range. Because this is an analog adjustment, it allows for fine-tuning without introducing digital "glitches" or abrupt phase jumps, which is critical for maintaining the integrity of complex, continuously modulated signals.

- **IF Equalization:** An internal equalizer setting can be enabled to apply a positive slope across the IF band, which is highly useful for compensating for frequency-dependent cable loss in external test setups.
- **IF Filtering:** A set of IF filters is provided and can be used where needed to supress unwanted mix harmonics that may enter the RF port.

RF Chain Architecture

- **Reversible Amplification:** The RF chain utilizes intelligent, reversible amplifiers. The system automatically configures the direction of these amplifiers based on whether the user has selected up-conversion or down-conversion, ensuring seamless operation.
- **Dynamic Filtering Stages:**
  - *Primary Filter:* Positioned directly after the mixer, this selectable filter removes LO leakage and aggressively suppresses the unwanted sideband generated during the frequency conversion process.
  - *Secondary Filter Bank:* An additional set of selectable bandpass filters provides further sideband and LO suppression. During down-conversion, these filters are highly effective at isolating the desired input signal and rejecting out-of-band interference before it reaches the mixer.
- **Digital Step Attenuation & Level Management:** The RF output features a robust 2-bit digital attenuator with selectable steps of **0, 16, 32, and 48 dB**.
  - *Best Practice for Small Outputs:* If a low-power output signal is required, it is highly recommended to perform the internal conversion at a relatively strong signal level (**-10 dBm to 0 dBm**) to maximize the Signal-to-Noise Ratio. Once converted, use this digital attenuator to drop the final output power. This method preserves optimal spur and LO suppression.
  - *Best Practice for Large Inputs:* Conversely, when down-converting, this attenuator can be used to pad down high-power RF input signals, preventing the mixer from being driven into non-linearity and distortion.

Operating Instructions

Initial Power-Up and Communications

When the unit is powered, for convenience it remembers and starts up in the previously configured state. If the oven, or any of the channels / conversion was previously enabled it will be enabled on the next power up. The unit can be powered either from DC jack or USB-C.

The unit is controlled via the provided USB-C port. The unit uses a standard FTDI device for its communications and a virtual comport will be installed on the PC when it is connected. The baud rate is 100,000 BPS. To check which port the PC has allocated to the device open device manager and comports. The comport can be changed in port settings and each converter remembers the comport each time it is plugged into a PC. This enables multiple converters to be controlled from a single computer.

Thermal Oven

All RF devices exhibit change in RF performance with temperature. The unit consumes varying RF power whether a single chain is used and whether it is configured as up or down. This along with ambient temperature changes this would result in a drift of conversion gain. A thermal oven is employed to top off the modules temperature and keep it operating at a constant temperature regardless of the internal settings or outer temperature.

The module should not be heavily heatsinked otherwise it will not be able to maintain temperature. The units power use is around 10 watts in standard operation with the oven able to deliver a further 6 watts of power.

The set temperature can be changed if required. For bench use in room temperature a set point of 46C is recommended.

Bi-Directional RF-IF Conversion Setup

Each channel can be programmed for up conversion or down conversion or can be disabled. When it is disabled the channel powers down. The amplifiers are reversed automatically depending on whether up conversion or down conversion is selected.

Configuring Optimal Frequency Plans

The selectable filter settings are key to obtaining a spur and image free conversion. There are selectable filters in the IF on the input, in the RF after the mixer and on the RF at the input.

IF Filters

The IF chain has 8 possible selections. 8 is a pass through, 7 is an equalizer with positive slope vs frequency. This may be used if some equalization is required. The bands 3 to 8 can be selected as follows:

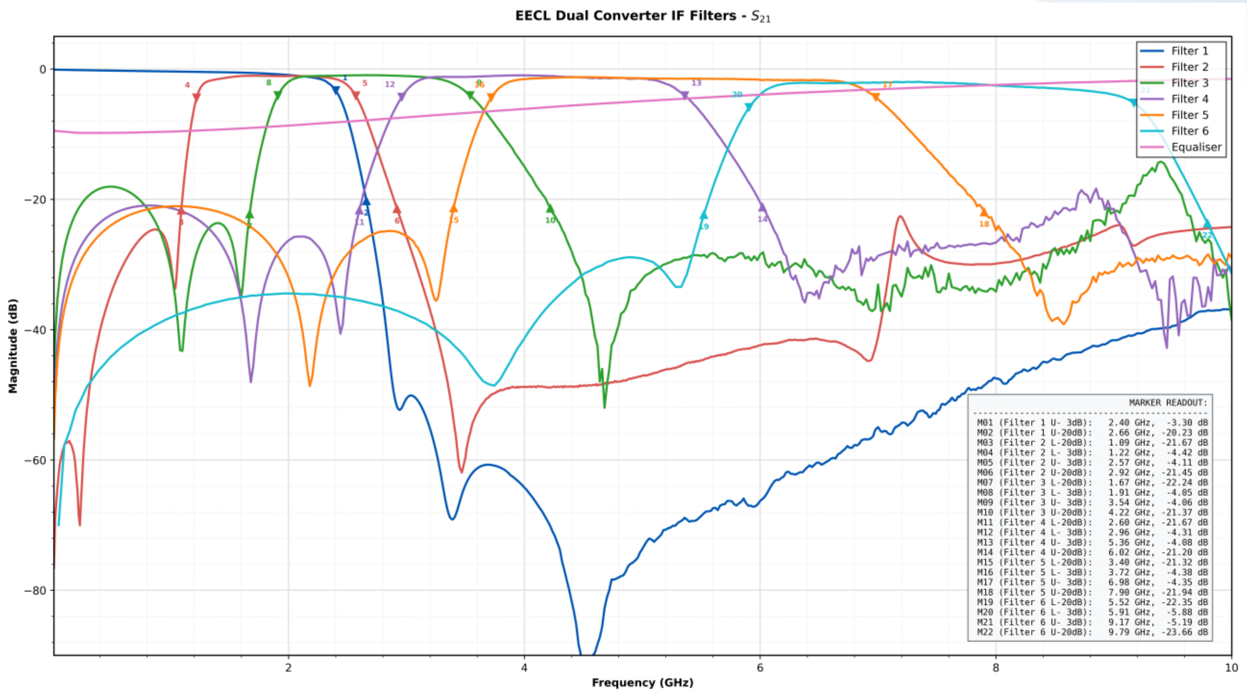


Figure 5: Plot showing overlapping IF filter selections

Filter Band	Lower 20dB (GHz)	Lower 3dB (GHz)	Upper 3dB (GHz)	Upper 20dB (GHz)
1	0	0	2.4	2.66
2	1.09	1.22	2.57	2.92
3	1.67	1.91	3.54	4.22
4	2.6	2.96	5.36	6.02
5	3.4	3.72	6.98	7.9
6	5.52	5.91	9.17	9.79
7	Positive Equalizer	Positive Equalizer	Positive Equalizer	Positive Equalizer
8	Pass Through	Pass Through	Pass Through	Pass Through

RF Filters

The module internally uses two different mixers which are selected depending on the LO frequency. Mixer 1 is the band from 8GHz to 16GHz and Mixer 2 is the band 16GHz to 32GHz. The filters for each band have 4 settings where 1 is a pass through and 2,3 and 4 are the following selectable filters.

It is important to point out that there are two filter banks in the RF path. The first bank suppresses the LO to avoid RF gain compression and the second filter bank adds to the filtering. So the suppression shall be twice that of the selected filter bank.

LO Range (8 to 15.99 GHz)

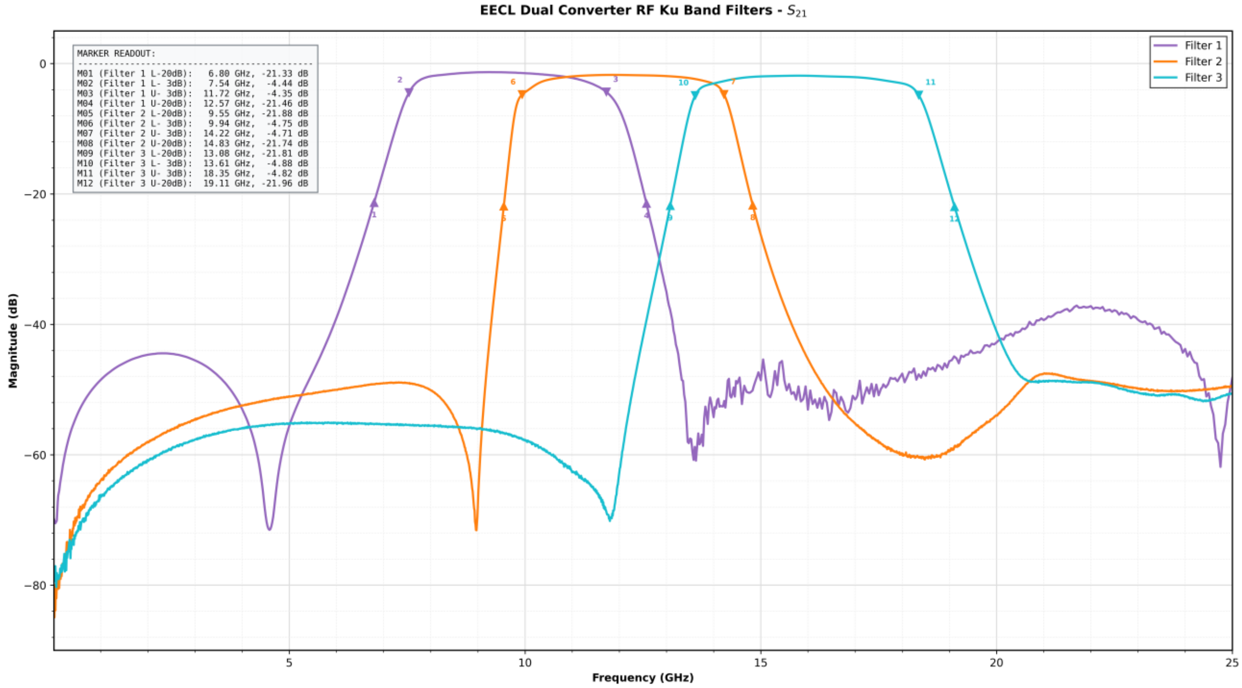


Figure 6: Plot showing overlapping RF Mixer 1 Configurations

Filter Band	Lower 20dB (GHz)	Lower 3dB (GHz)	Upper 3dB (GHz)	Upper 20dB (GHz)
1	6.8	7.54	11.72	12.57
2	9.55	9.94	14.22	14.83
3	13.08	13.61	18.35	19.11
4	Pass Through	Pass Through	Pass Through	Pass Through

LO Range (16 to 32 GHz)

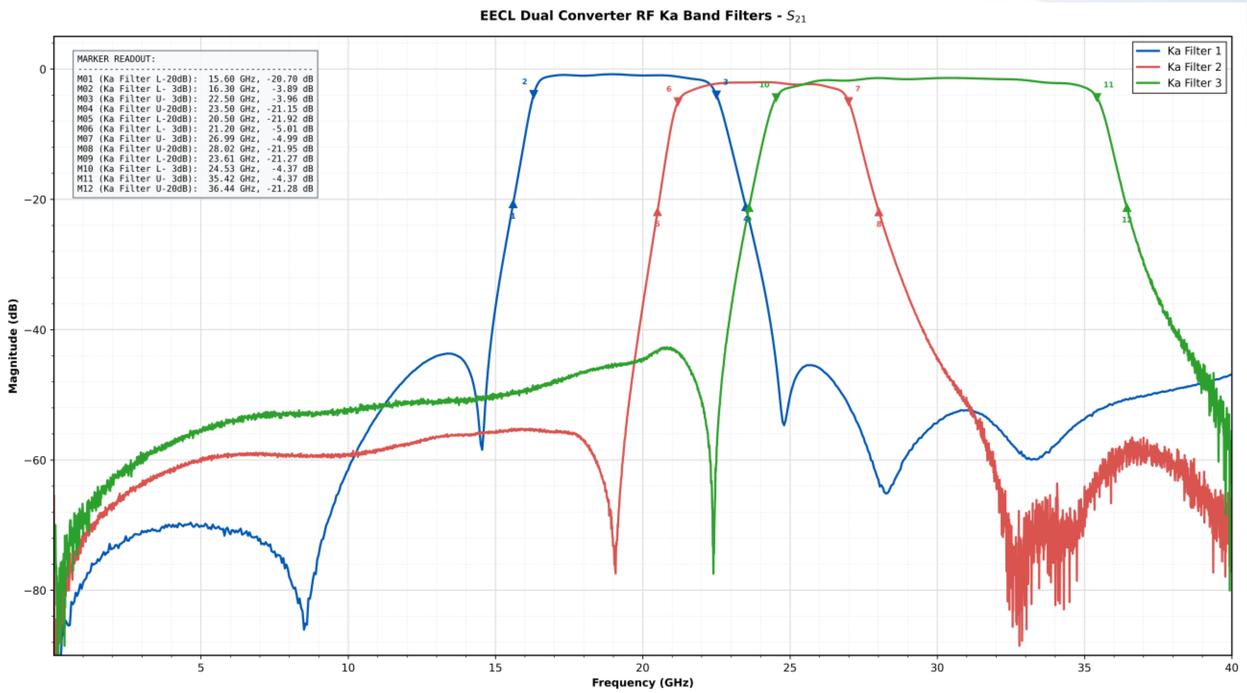


Figure 7: Plot showing overlapping RF Mixer 2 Configurations

Filter Band	Lower 20dB (GHz)	Lower 3dB (GHz)	Upper 3dB (GHz)	Upper 20dB (GHz)
1	15.6	16.3	22.5	23.5
2	20.5	21.2	26.99	28.02
3	23.61	24.53	35.42	36.44
4	Pass Through	Pass Through	Pass Through	Pass Through

Suggested Frequency Plan

An optimal frequency plan is shown below that covers the entire RF range, this plan shows how we would use the module. It is expected that the user shall alter the IF frequency to correctly fit the desired RF frequency. Other configurations are possible and the user should consult the provided filter plan and calculate using mixer sum and difference from the LO to determine operational frequencies. We make use of a combination of LSB and USB in the frequency plan where the entire RF range is covered with band overlap.

	IF	LO	RF Lower	RF Upper	Filter Bank
Ku Band	5.5	13.5	8	19	1
	4.5	13.5	9	18	1
	3.5	13.5	10	17	1
	2.5	13.5	11	16	1
	4.5	15.5	11	20	2
	3.5	15.5	12	19	2
	2.5	15.5	13	18	2
	1.5	15.5	14	17	2
	3	11	8	14	3
	3.5	11	7.5	14.5	3
	4.5	11	6.5	15.5	3
	6.5	11	4.5	17.5	3
Ka Band	7	24.5	17.5	31.5	1
	6.5	24.5	18	31	1
	5.5	24.5	19	30	1
	4.5	24.5	20	29	1
	3.5	24.5	21	29	1
	3	24.5	21.5	27.5	1
	2.5	19	16.5	21.5	2
	3.5	19	15.5	22.5	2
	4.5	19	14.5	23.5	2
	5.5	19	13.5	24.5	2
	6	19	13	25	2
	2	22.5	20.5	24.5	3
	3	22.5	19.5	25.5	3
	4	22.5	18.5	26.5	3
	5	22.5	17.5	27.5	3
	6	22.5	16.5	28.5	3
	8	22.5	14.5	30.5	3

Figure 8: Suggested Frequency Plan

Adjusting Gain Control

The gain of each chain can be adjusted independently. For fine non interrupted control it is recommended to adjust the IF VVA. This can be used to fine tune the gain without glitching the RF. For large gain changes the DCA should be used which is directly on the RF port. Changing this setting will cause an abrupt jump in the RF path as the switch occurs. Plots of the gain range are shown later in the document in the technical specification section.

Software and Remote Control

Using the Web GUI *(No-installation option)*

A web GUI is provided to control the module. This is the easiest way to get up and running quickly. The GUI can be run directly from the EECL website, alternatively the HTML can be downloaded and run on any computer. The GUI is a HTML coded interface that makes use of direct comport access provided in most new browsers.

The converter settings can be changed in the GUI once connected and a display showing the commands and data transferred is shown to help with programming.

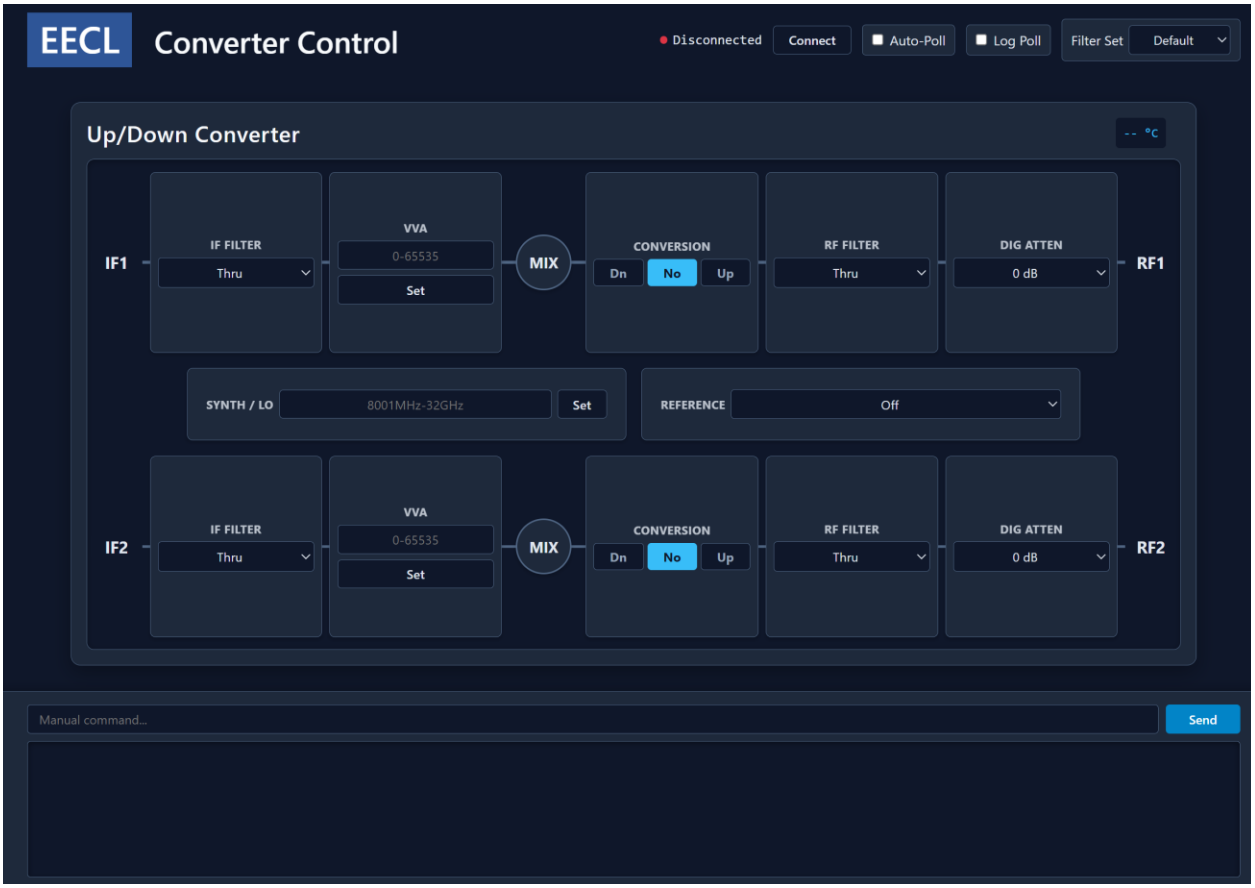


Figure 9: Converter Web GUI

Scripting and Automation (Python, MATLAB, and LabVIEW libraries)

A separate programming manual is provided to allow custom code to be written to control the module.

Technical Specifications

The following pages show a brief outline of expected performance, a full set of test data is available on the EECL website. We have tried to measure most combinations of filters, sidebands and LO settings.

Amplitude and Gain Specifications

The following plots show typical conversion gains that are obtained at various bands. A full list of data is available on our website showing many more possible conversions. The converter conversion gain over any 200MHz band signal is extremely flat. The following plots show the VVA range and the digital attenuator range. Combined between the VVA and DCA they give a total of 80dB of attenuation range.

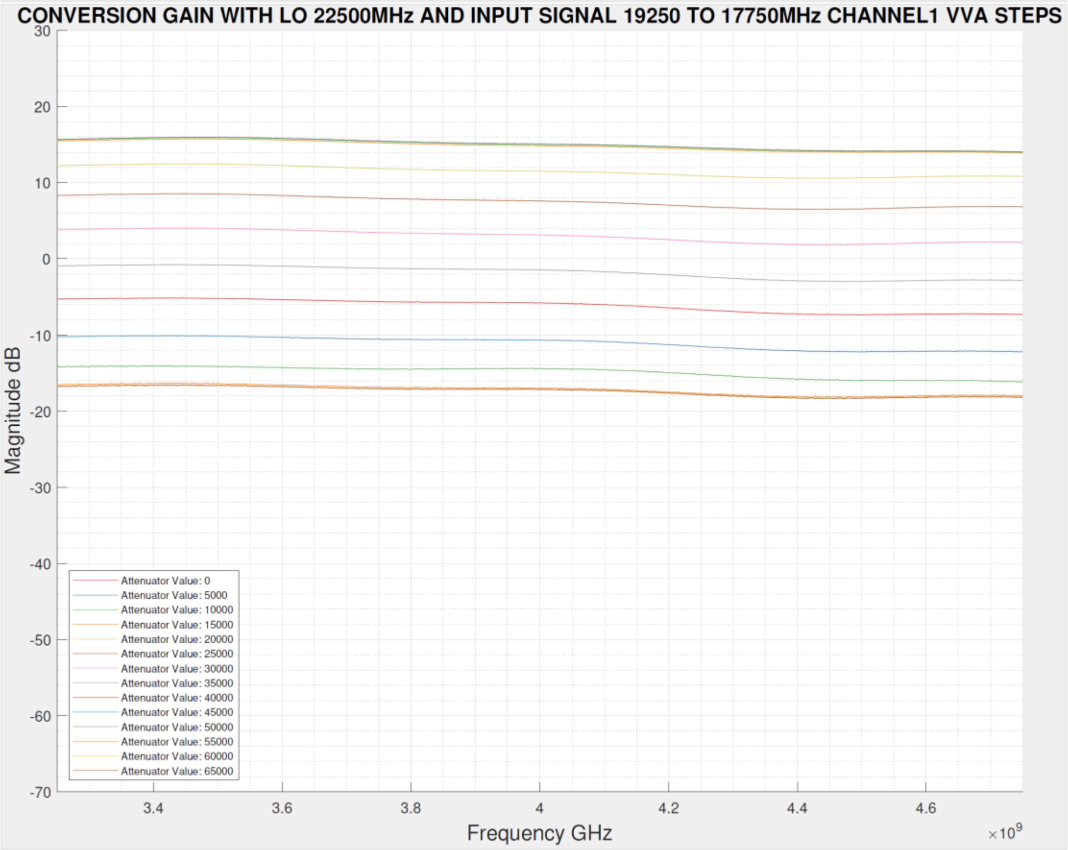


Figure 10: Voltage Variable Attenuator Range

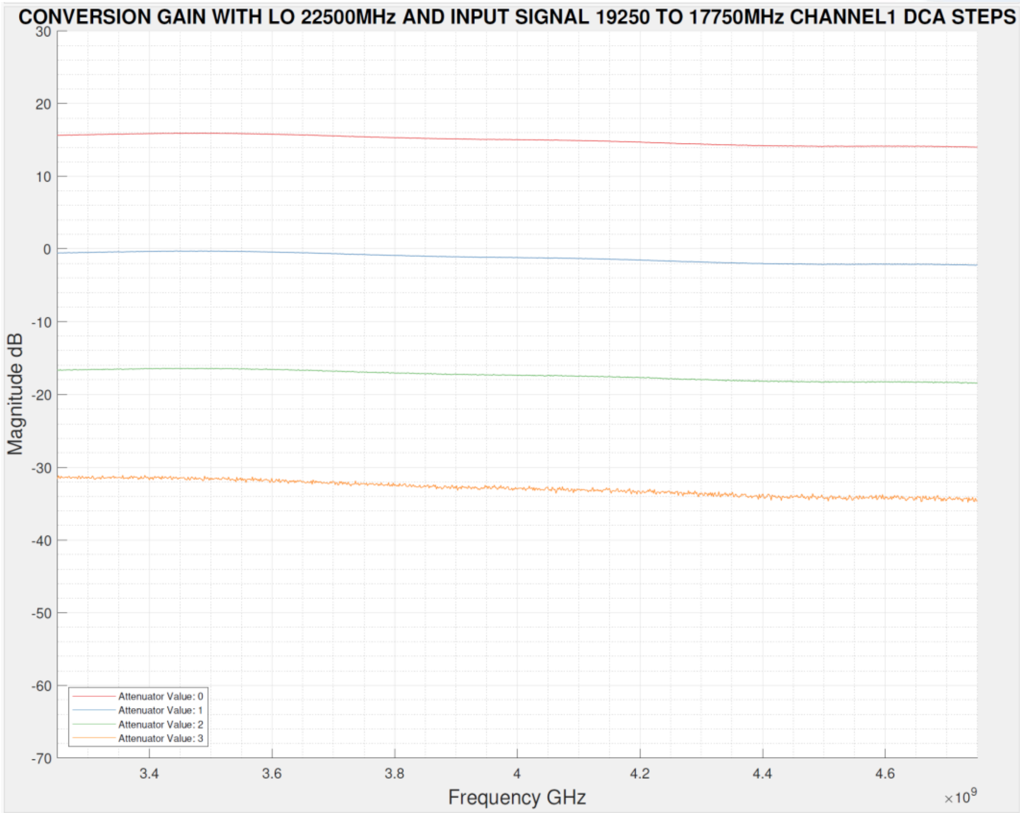
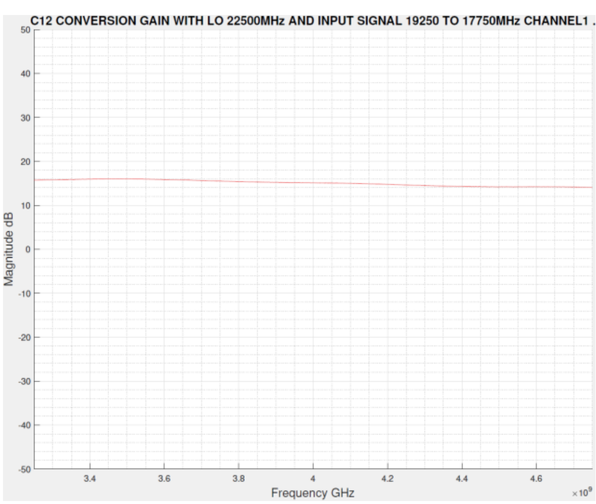
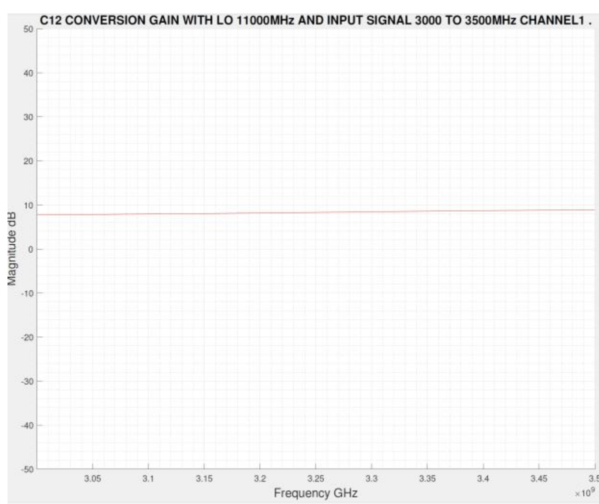


Figure 11: Front RF Digital Attenuator Range (2bits)

The following plots show typical conversion gain at minimum attenuation for some of the typically used LO settings and bands. A full set of test data is available from EECL.





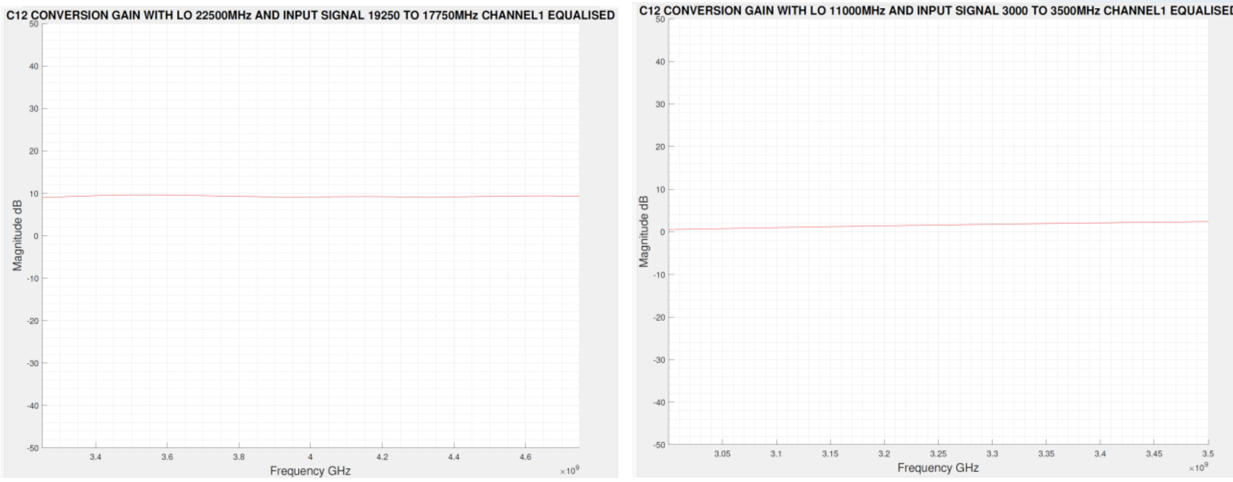
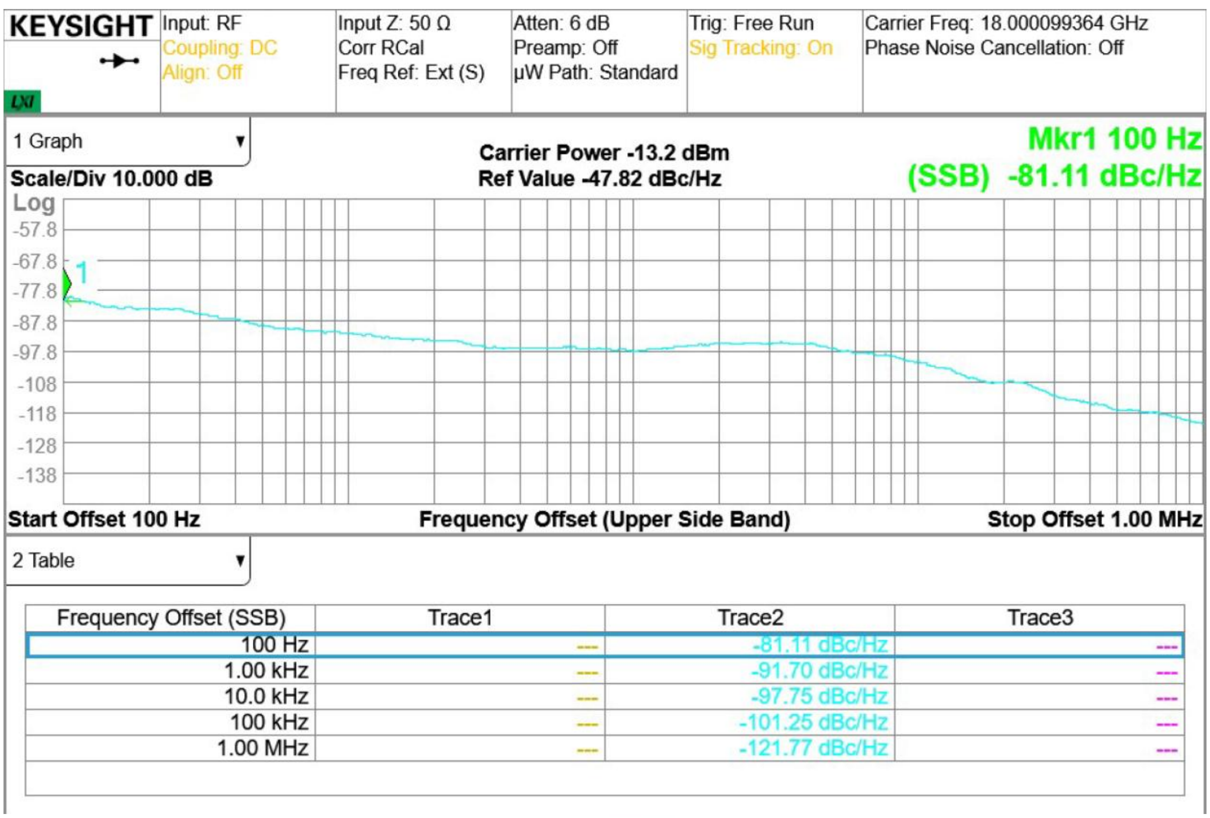


Figure 12: Various conversion gain typical plots

Phase Noise Plots

The local oscillator (LO) has the following phase noise profiles when set at 18GHz. Access to the LO direct is provided by the side SMPM connectors. This phase noise profile is typical for most LO frequency settings.



Frequency Offset (SSB)	Trace1	Trace2	Trace3
100 Hz	---	-81.11 dBc/Hz	---
1.00 kHz	---	-91.70 dBc/Hz	---
10.0 kHz	---	-97.75 dBc/Hz	---
100 kHz	---	-101.25 dBc/Hz	---
1.00 MHz	---	-121.77 dBc/Hz	---

Spur Plots

The following plots show typical spur performance. It can be seen that when the right filters are used the conversion is extremely clean. A full set of results is available on the website.

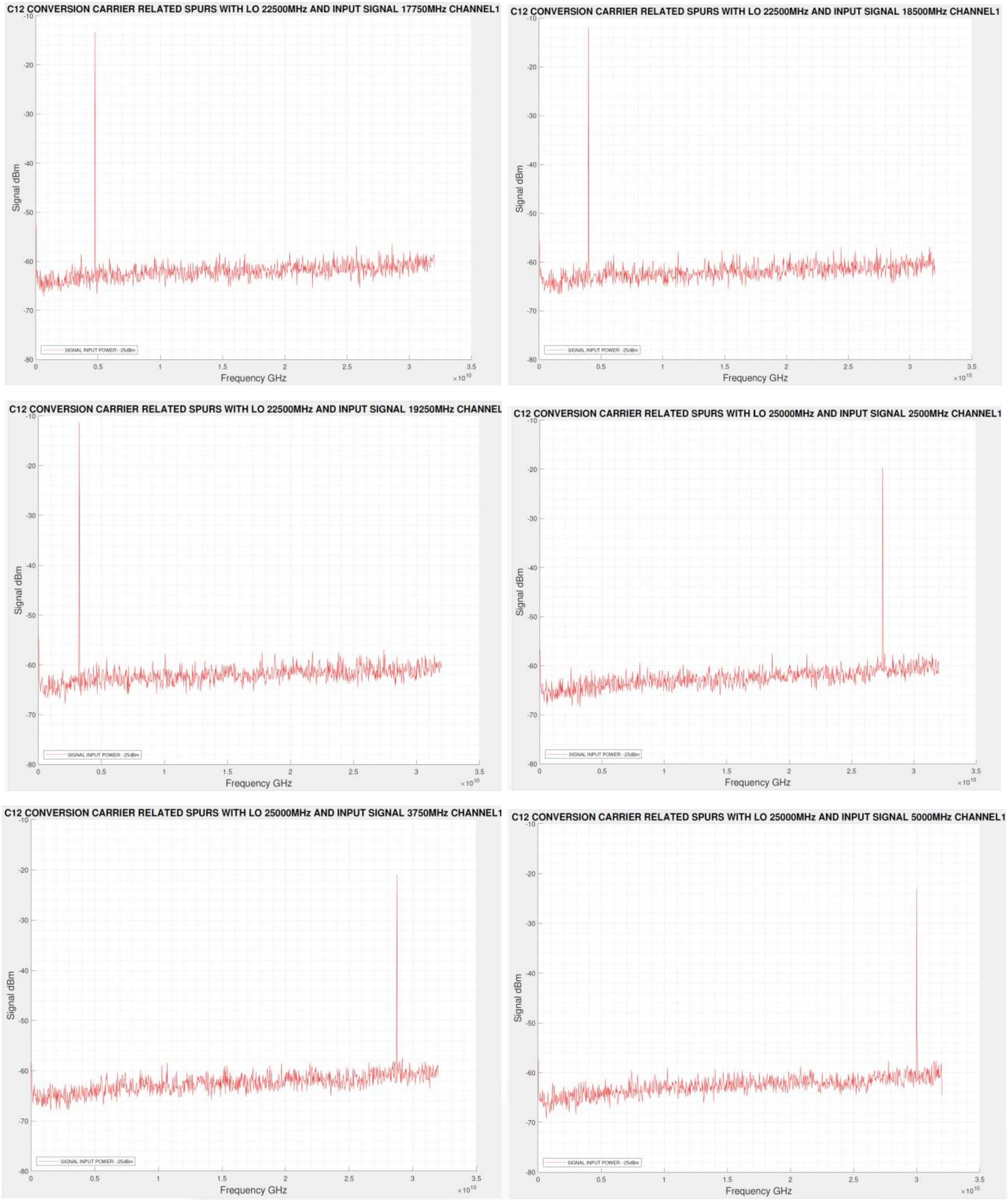


Figure 13: Various typical spectral plots of conversion

Spectral Purity with EVM (digital modulation) measurement

The converter has been measured in performance for the up converting and down converting of 125MHz and 230MHz bandwidth 16QAM signals. The following plots show the performance at 14GHz, 19.25GHz, 21.5GHz and 30GHz where an EVM of 41.2dB, 35dB, 31dB and 30dB is obtained. These numbers are considered extremely good for such a wideband with signal. A full set of data is available on the website.

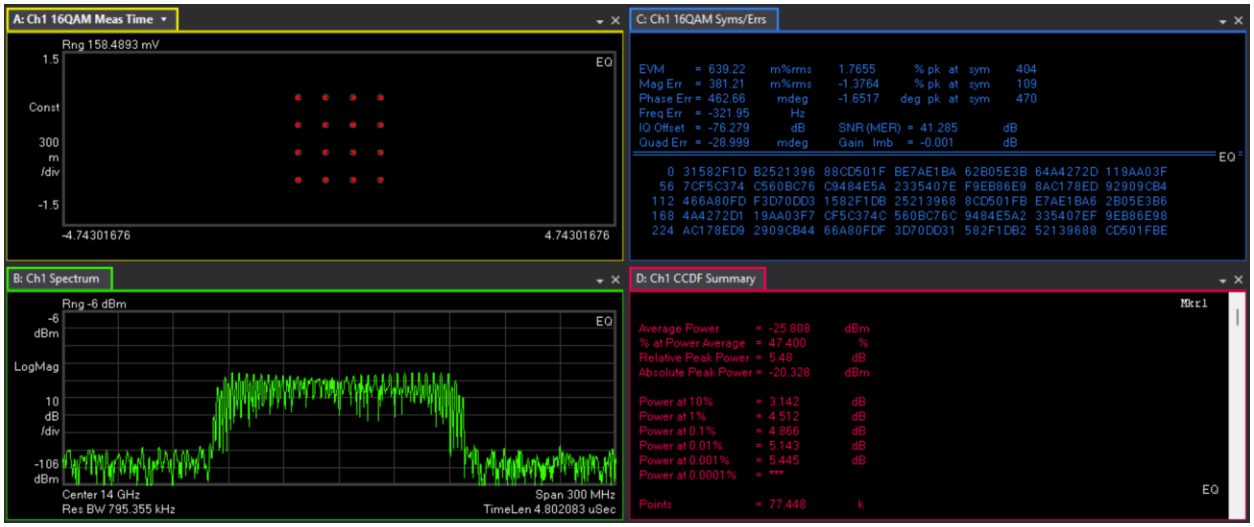


Figure 14: 16QAM @ 14 GHz

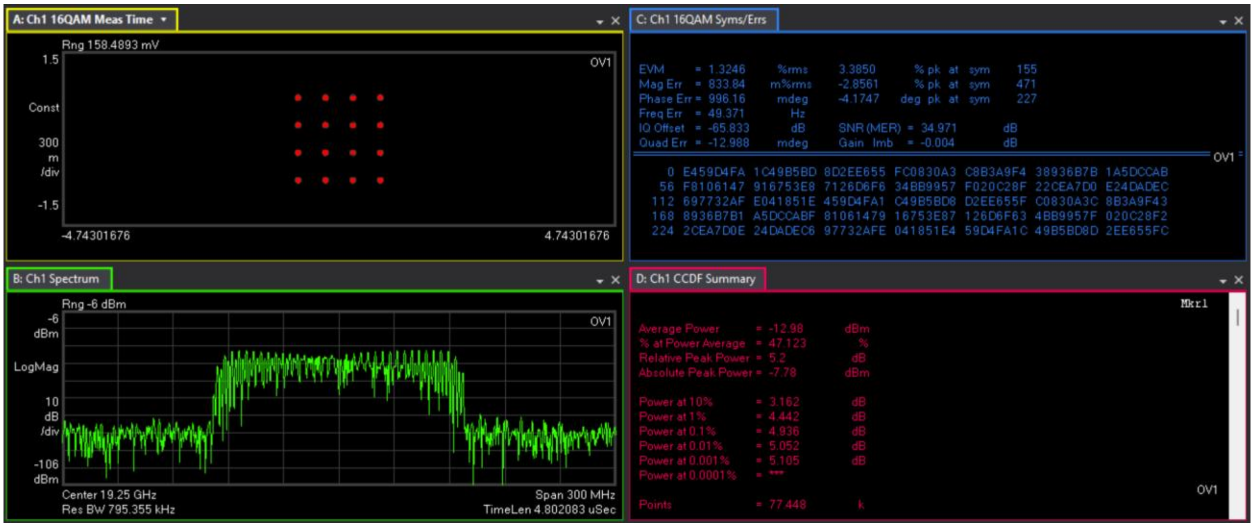


Figure 15: 16QAM @ 19.25GHz

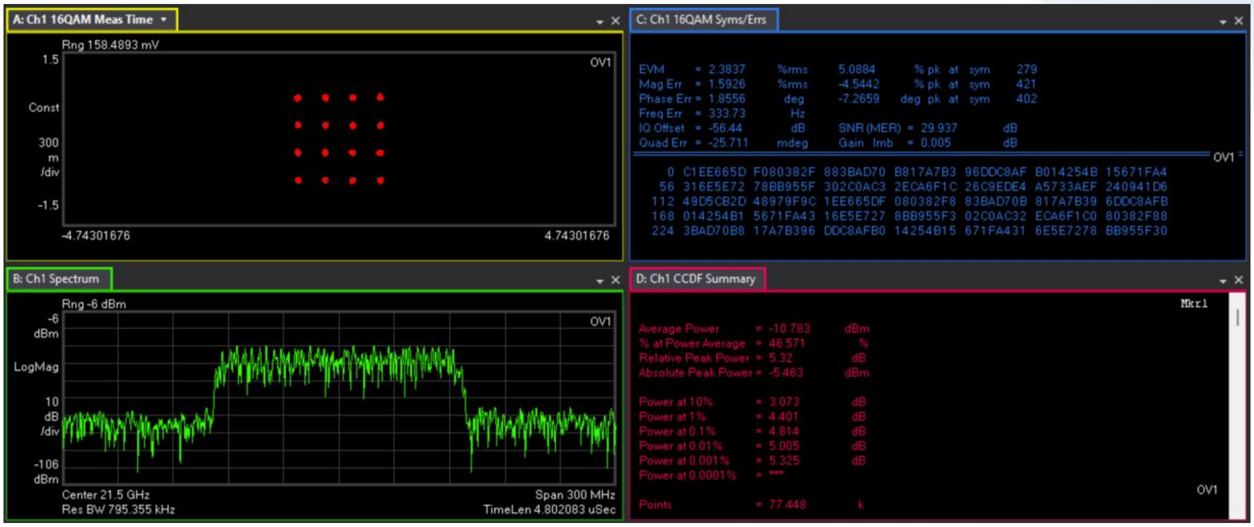


Figure 16: 16QAM @ 21.5GHz

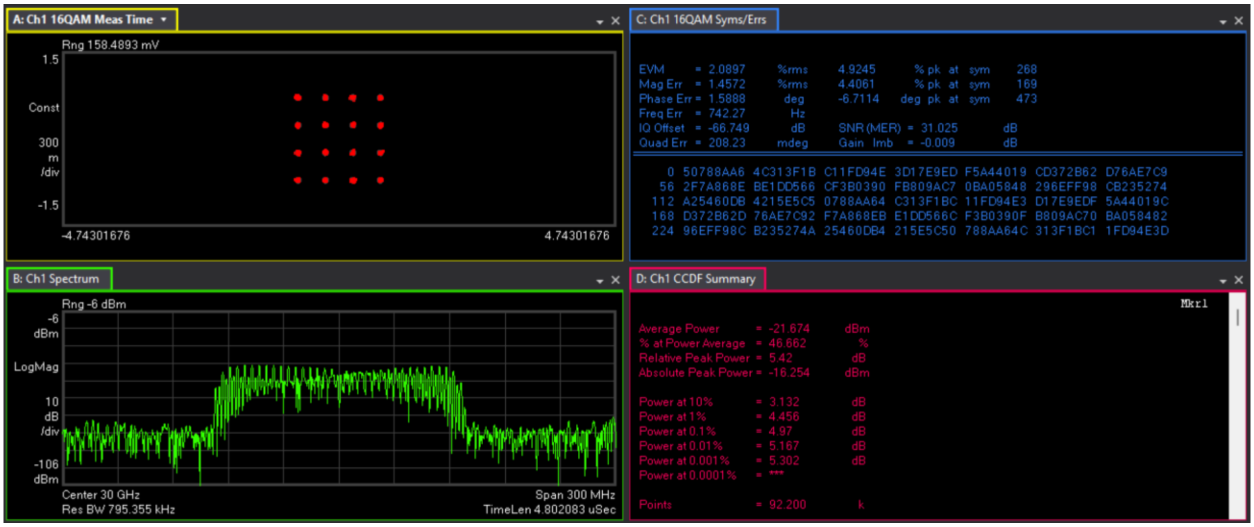


Figure 17: 16QAM @ 30GHz

Troubleshooting and Maintenance

The following recommendations are made for care of the module.

The converter module has an onboard microprocessor running firmware. This can be updated via USB. Unless there is a valid reason to update it then it should not be attempted.

Keep the module away from extreme heat, high vibration, and humidity. The module is designed to be operated in a laboratory environment and not outside continuously.

Take care of the 2.92mm connectors and the SMAs they can be broken if mated incorrectly.

Take care of ESD discharge, even though the module has some internal protection it is advised not to expose it to unnecessary ESD.

Support

Contacting EECL Technical Support

Please contact us at info@euroecl.com for any questions, technical information or general information.