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Filtering a 10 MHz TTL Square Wave into a Sinewave with a 7-Pole Chebyshev Low-Pass Filter

Device:	**PRL-LPF7-12MHz**			
Tested By:	Steven Kan			
Date:	27 August 2020			
Equipment:	**PRL-175A-10**	**PRL-414B-SMA**	**DPO3054**	**HP 3585A**
S/N:	ENG	1L412063	C012732	1750A02039

Introduction:

This experiment tested the ability to filter a 10 MHz TTL square wave from a PRL TTL fanout buffer into a 10 MHz sinewave, using a 7-pole Chebyshev Low-Pass filter designed for a 3 dB cutoff frequency of 12 MHz.

Methodology:

The **PRL-175A-10** supplies a crystal-based, 10 MHz TTL clock signal. The output was cabled into a **PRL-414B-SMA** fanout buffer to provide 4 identical copies. Output **Q1** of the **PRL-414B-SMA** was measured with an **HP 3585A Spectrum Analyzer** both with and without the **PRL-LPF7-12MHz** filter in series. Output **Q1** was then captured on an oscilloscope with the filter in series, alongside output **Q2** without any filtering.

The filter, model number **PRL-LPF7-12MHz**, was constructed using a **PRL-MNET-SMF Signal Conditioning Kit**. Ideal component values were calculated using an **online filter calculator** (**Lowpass, 7 pole, 12 MHz, 50 Ω**) and then the closest standard values were used to approximate the calculated design, as follows:

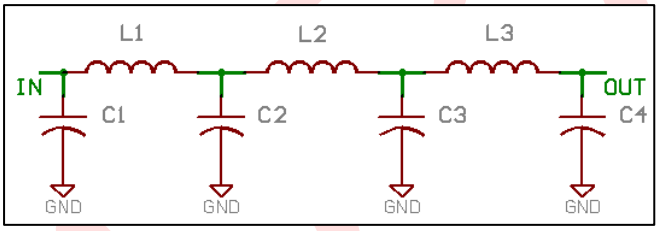

Fig. 1: Filter Schematic

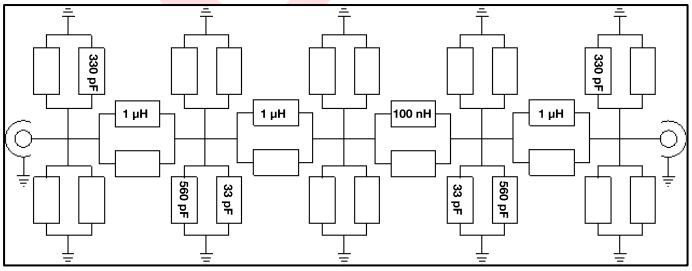

Fig. 2: Component Placement on PRL-MNET-SMF

Part Values				
0.1 dB Ripple Chebyshev				
Part	**Calculated**	**Unit**	**Actual**	**Err.**
L1	1.01	uH	1.0	2%
L2	1.11	uH	1.1	2%
L3	1.01	uH	1.0	2%
C1	334.62	pF	330	5%
C2	593.97	pF	593	5%
C3	593.97	pF	593	5%
C4	334.62	pF	330	5%

Table 1: Component Values

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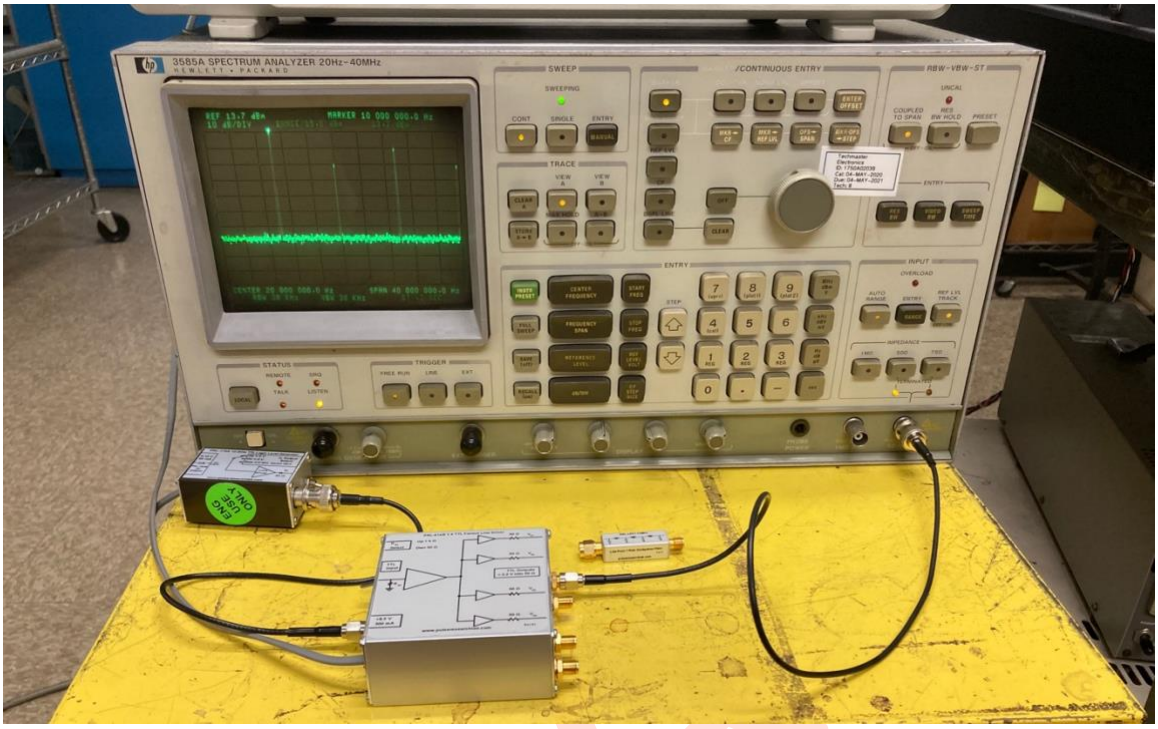
Measurements:



The **PRL-175A-10** produces a clean TTL square wave with good symmetry. Although the **PRL-175A-10** is capable of driving a 50 Ω load directly, the **PRL-414B-SMA** was used to re-buffer the signal, as the customer will be using this device to buffer a signal from an FPGA that will not drive a 50 Ω load. The TTL-compatible output circuit of the **PRL-175A-10** shares the same design as that of the **PRL-414B-SMA**.

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With no filter in place, the power at **10 MHz** is **+13.6 dBm**, with the expected peaks at the harmonics of **20 MHz**, **30 MHz**, and **40 MHz**, as shown below. Screen captures from the **HP 3585A** were taken over GPIB via the **7470.exe HP 7470A Plotter Emulation Tool** (part of the freely available **KE5FX GPIB Toolkit**), and then converted from PLT to PostScript format using the freely available **HP-GL Viewer**):

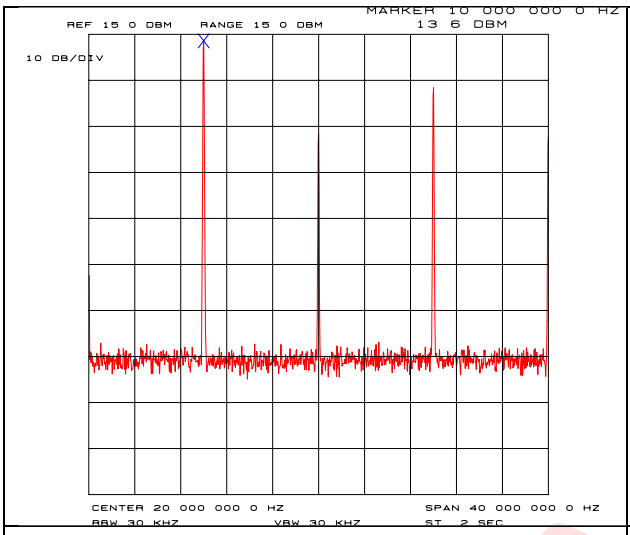

Fig. 3: PRL-175A →PRL-414B-Q1→HP3585A +13.6 dBm at 10 MHz

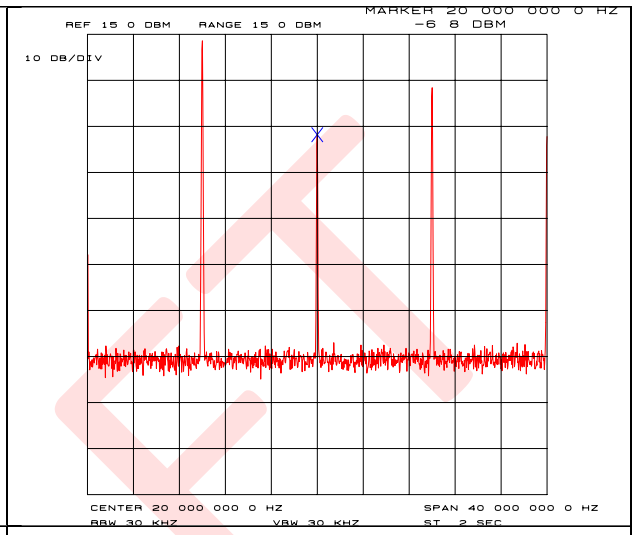

Fig. 4: PRL-175A →PRL-414B-Q1→HP3585A -6.8 dBm at 20 MHz

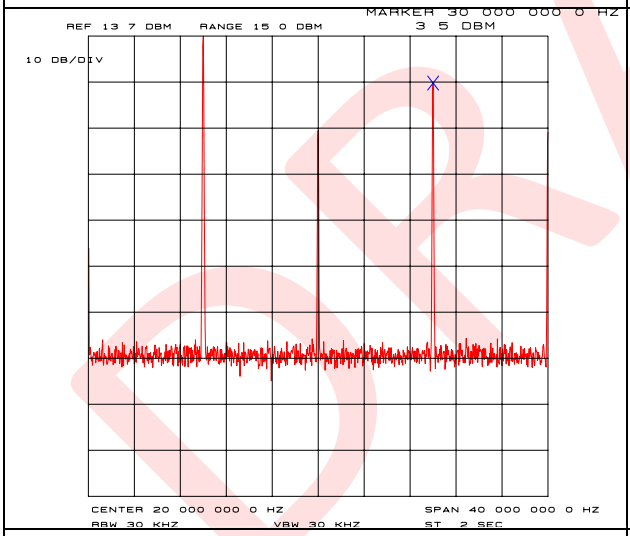

Fig. 5: PRL-175A →PRL-414B-Q1→HP3585A +3.5 dBm at 30 MHz

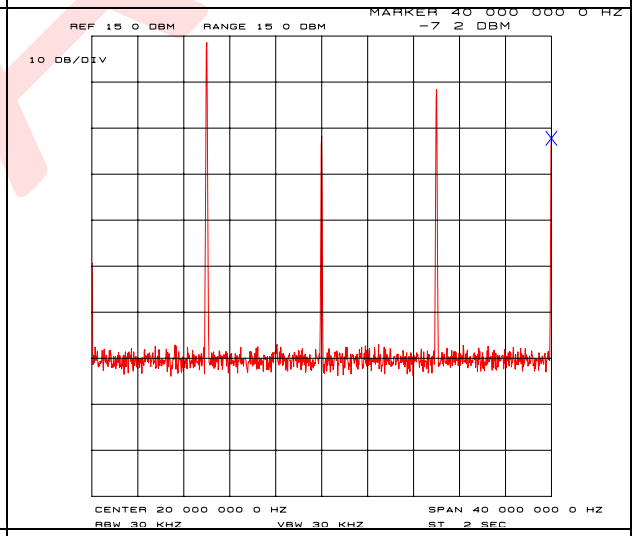

Fig. 6: PRL-175A →PRL-414B-Q1→HP3585A -7.2 dBm at 40 MHz

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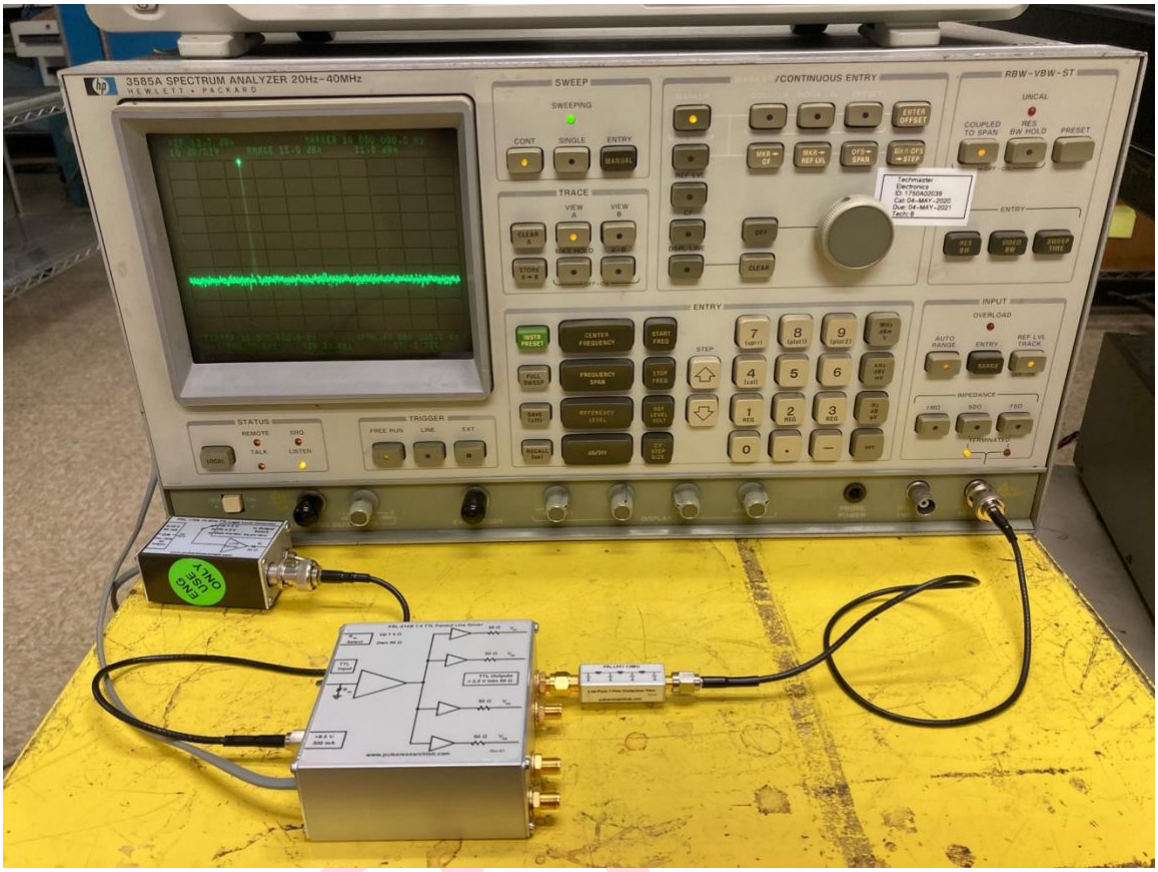
With the baseline established, we installed the filter directly onto the output of the **PRL-414B-SMA**:



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The power at the fundamental **10 MHz** frequency is slightly attenuated down to **+11.7 dBm**, and the power at the harmonics is reduced to within the noise floor of the measurement setup, approximately -60 dBm:

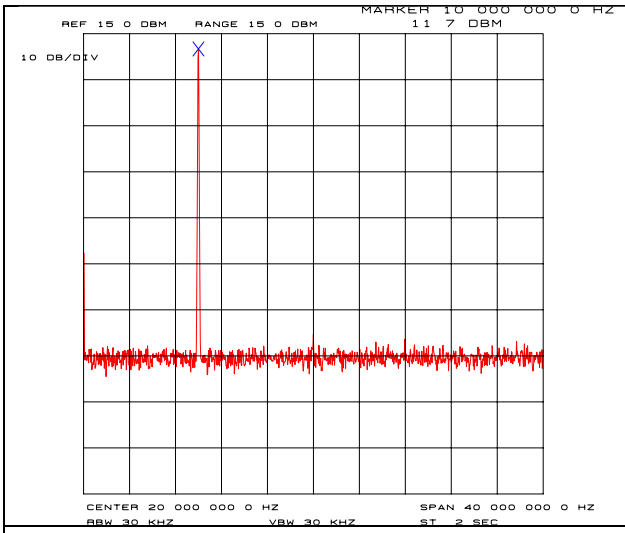

Fig. 7: PRL-175A →PRL-414B-Q1→ PRL-LPF7-12MHz→HP3585A +11.7 dBm at 10 MHz

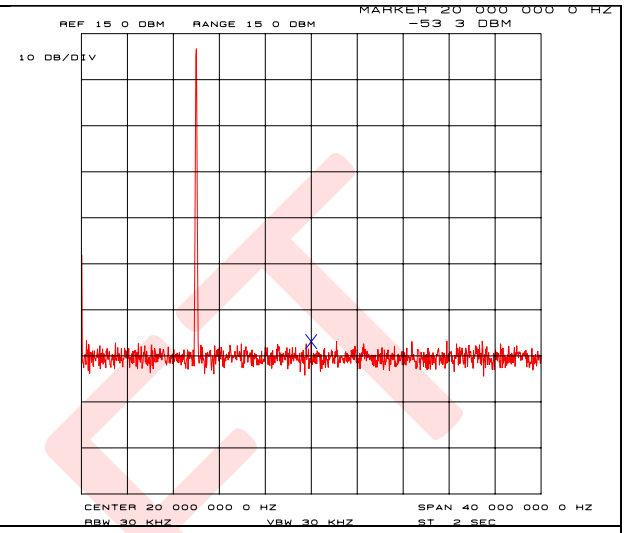

Fig. 8: PRL-175A →PRL-414B-Q1→ PRL-LPF7-12MHz→HP3585A -53.3 dBm at 20 MHz

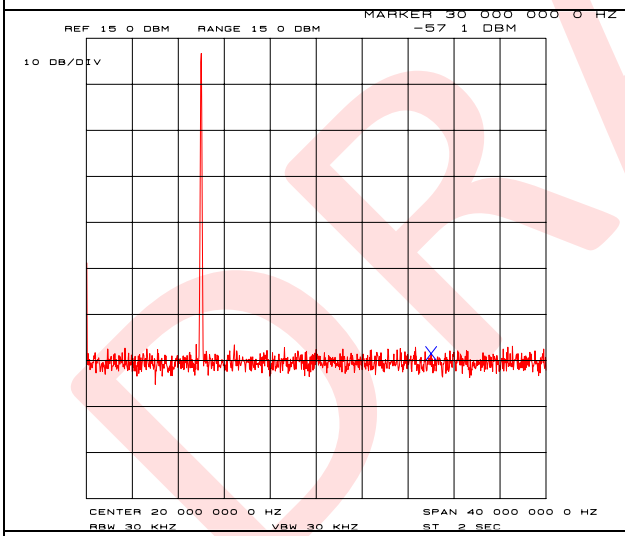

Fig. 9: PRL-175A →PRL-414B-Q1→ PRL-LPF7-12MHz→HP3585A -57.1. dBm at 30 MHz

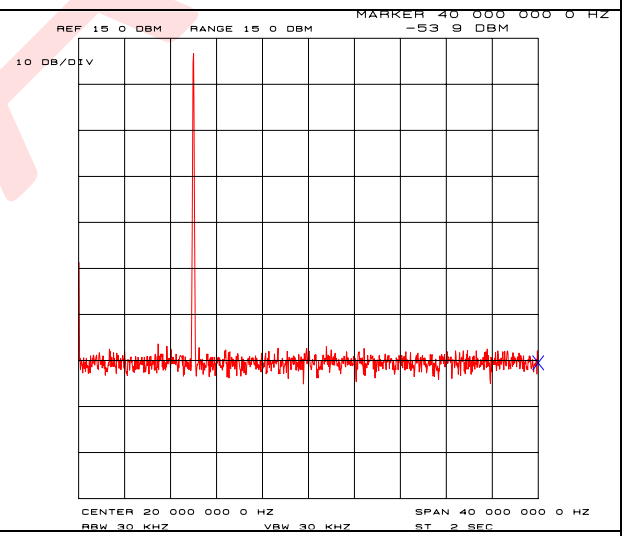

Fig. 10:PRL-175A →PRL-414B-Q1→ PRL-LPF7-12MHz→HP3585A -53.9 dBm at 40 MHz

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Actual vs. **Modeled** attenuations are compared below, where any measurements below approximately -60 dBm are below the noise floor of the measurement setup:

Freq (MHz)	Power (dBm)		Attenuation: (dBm)	
	Original	Filtered	Actual	Modeled
10	+13.6	+11.7	-1.9	-0.1
20	-6.8	-53.3	-46.5	-49.4
30	+3.5	-57.1	-60.6	-78.2
40	-7.2	-53.9	-46.7	-95.8

We then cabled the **PRL-414B-SMA** into a 500 MHz oscilloscope (**DPO3054**), both with and without the filter. Screen captures were taken directly into MS Word via the TekVISA Toolbar. The **PRL-414B-SMA** exhibits excellent symmetry across its 4 outputs, so output **Q2** is a very good proxy for **Q1** without the filter installed.

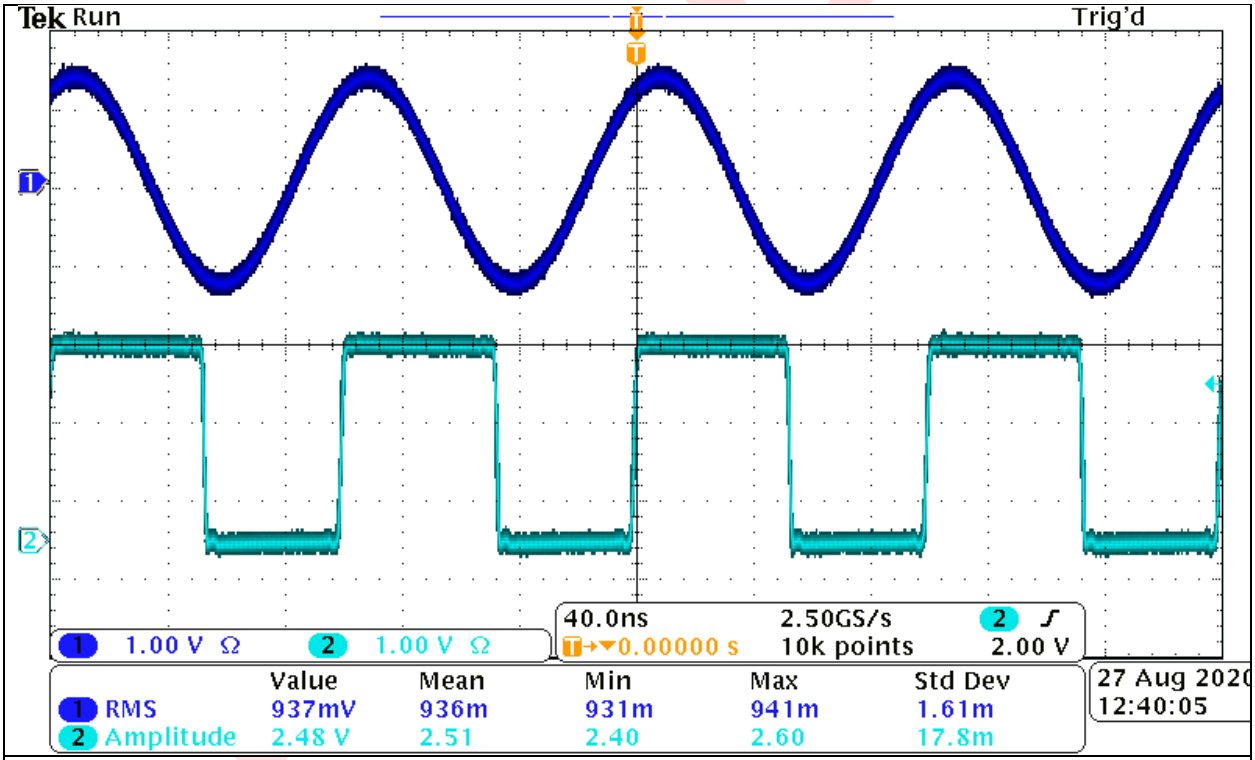

Fig. 11: PRL-175A → PRL-414B-Q1→PRL-LPF7-12MHz→DPO3054 Ch. 1/50 Ω
PRL-414B-Q2→DPO3054 Ch. 2/50 Ω

Conclusion:

The **PRL-LPF7-12MHz** does an excellent job filtering a 10 MHz TTL square wave from the **PRL-414B-SMA** into a clean sinewave with good spectral purity and low loss at the desired frequency.