An Octal 10 MHz Distribution Amplifier

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● Introduction

This paper describes an octal 10 MHz distribution amplifier module that provides eight isolated +7 dBm nominal outputs from a rubidium oscillator or similar frequency source, as shown in Figure 1. It comprises an input buffer and level detector, RF power splitting and eight output amplifiers, along with a DC/DC converter operating from a +24 VDC power supply. The front panel contains the eight BNC outputs (see Figure 2), while the rear panel holds the 5.5 mm OD x 2.5 mm ID DC power and BNC RF input connectors along with their respective indicators (see Figure 3).

Figure 1. Octal 10 MHz Distribution Amplifier

Figure 2. Front Panel

Figure 3. Rear Panel

● Description

A block diagram of the octal 10 MHz distribution amplifier is shown in Figure 4. The RF input is terminated with a 50 Ω resistor and the eight output amplifiers have 50 Ω resistors at their outputs, thereby providing good input and output return loss. The internal input buffer, power splitter and O/P amplifier paths also have 50 Ω interface impedances. The nine amplifiers all use LMH6723 wideband amplifiers. The input level detector provides an indication that an acceptable input signal is applied. The modular DC/DC converter has additional filtering at its output to further suppress ripple. Although indended for 10 MHz, this distribution amplifier will work satisfactorily from 1 to 25 MHz.

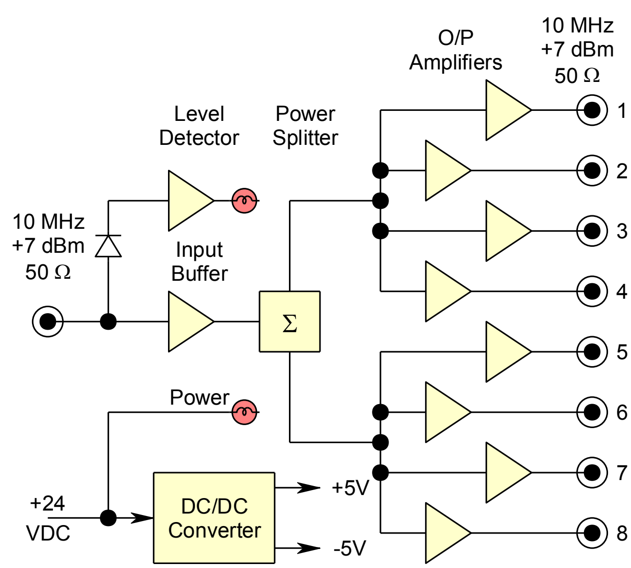


Figure 4. Distribution Amplifier Block Diagram

● Circuit

Schematics of the octal 10 MHz distribution amplifier are shown in Figures 5-8. The +7 dBm nominal 10 MHz input is buffered by a 3.5 dB gain 50 Ω input and output RF amplifier that drives a 2-way power splitter whose outputs each drive four output 0 dB gain 50 Ω input and output amplifier sections. The overall configuration thus has nominal unity gain from the RF input to each output. The power section comprises a well-filtered ±5 volt DC/DC converter that operates over an input range of +18 to +36 VDC (+24 VDC nominal).

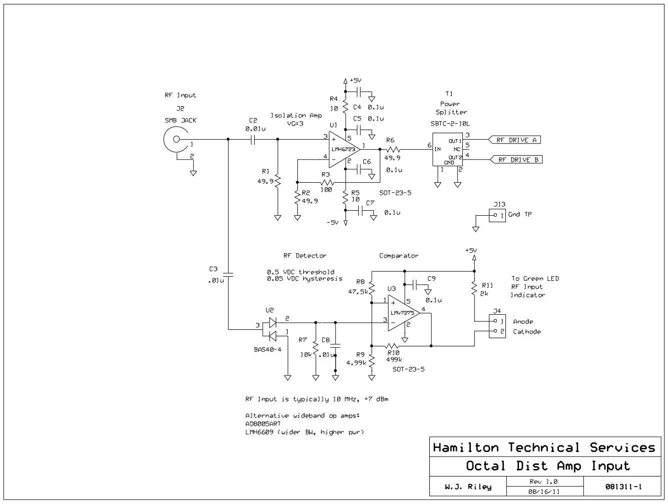


Figure 5. Input Section

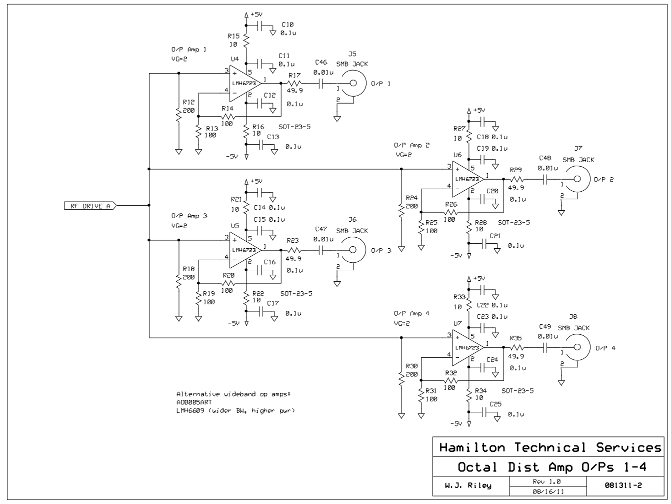


Figure 6. Output Amplifier 1-4 Section

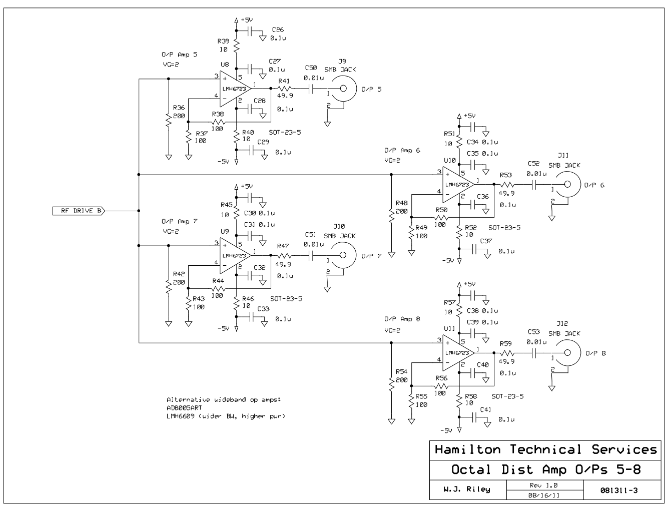


Figure 7. Output Amplifier 5-8 Section

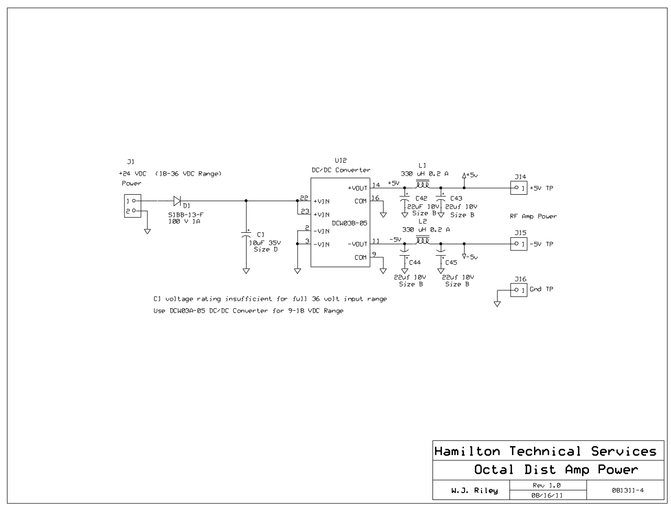


Figure 8. Power Section

● Board Layout

The 3.8" x 2.5" board layout of the octal 10 MHz distribution amplifier is shown in Figures 9 and 10. The board is double-sided with a nearly full ground plane on the bottom. All components are SMD type on the top side of the board. Besides the nine SMB RF connectors, there is a terminal strip for the DC input and a 2-position 0.1" header for the input level LED indicator. There are test points for the +5V and -5 volt supplies, and two ground TPs. Wire leads and an in-line connector are used for the LED to preserve a low profile. The board is attached to the case with four mounting screws.

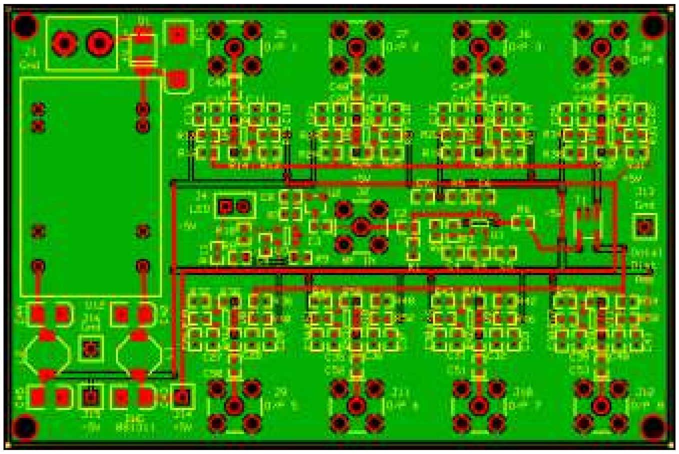


Figure 9. PWB Layout

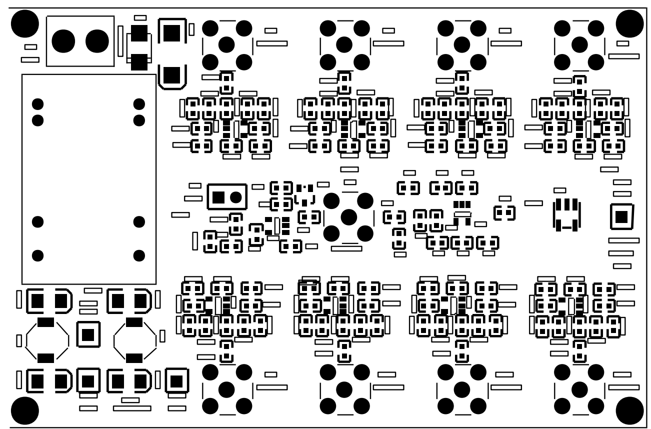


Figure 10. PWB Silk Screen

A photograph of the assembled distribution board is shown in Figure 11 and the complete unit in its initial test configuration is shown in Figure 12.

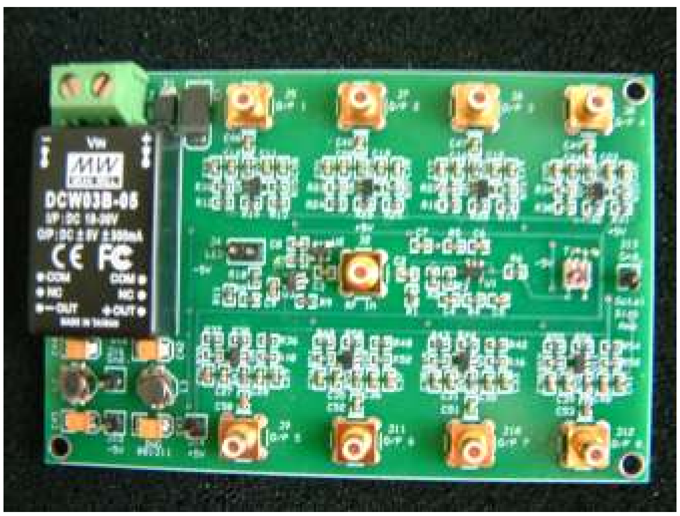


Figure 11. Assembled Distribution Amp Board

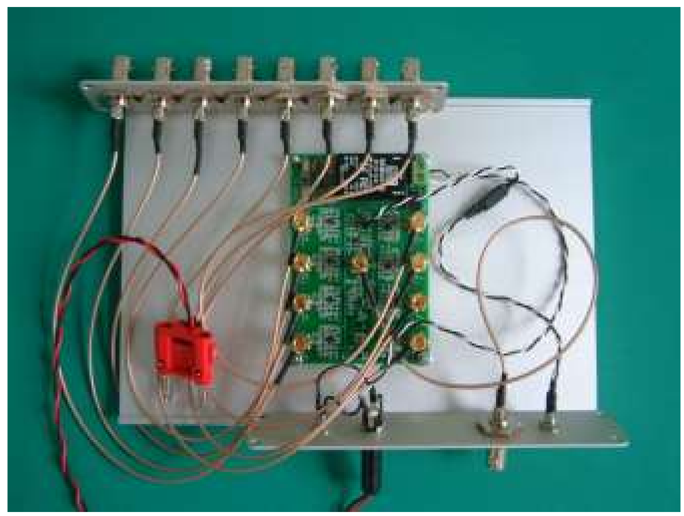


Figure 12. Initial Test Configuration

● Panel Assemblies

The front and rear panel assemblies of the octal 10 MHz distribution amplifier are shown in Figures 13 and 14 respectively.

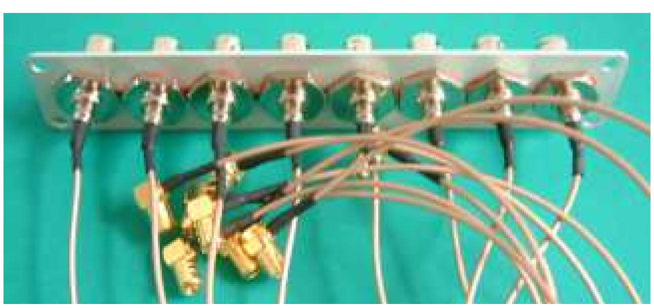


Figure 13 Front Panel Assembly

Figure 14 Rear Panel Assembly

The front panel has eight 12" right angle SMB plug to bulkhead BNC receptacle RG-178 cables for the RF output signals. The rear panel has one of these cables for the RF input signal, a Switchcraft Type 712A 5.5 mm OD x 2.5 mm ID DC connector and two panel mounted LEDs.

● **Instrument Packaging**

The octal 10 MHz distribution amplifier is housed in an 8.66" long x 6.50" wide x 1.20" high Hammond 1455R instrument case. This case was chosen as having the minimum width for the eight BNC RF output connectors and the minimum height to fit the board and its right angle SMB RG connectors. An interior view of the packaged unit is shown in Figure 15.

Figure 15. Interior View of Distribution Amp

● **Output Power**

The octal 10 MHz distribution amplifier has a nominal unity gain (0 dB). When driven at 10 MHz at +7.00 dBm, the output power at the eight outputs was measured as shown in the table below. The second bank appears to have about 0.1 dB higher gain, but all are outputs are close to nominal. There is no dependence of RF output power on the DC supply voltage, and the gain is essentially flat from 1 to 50 MHz. With a 50 Ω load, the output clips at 2 volts peak-to-peak (4 volts p-p no load) at a drive and output level of about +11 dBm.

Channel	1	2	3	4	5	6	7	8
O/P, dBm	+7.09	+7.10	+7.06	+7.09	+7.15	+7.19	+7.19	+7.19

● **Input Level Detector**

The input level detector indicates the presence of an input signal at a drive power of ≥ +5.3 dBm. Operation at lower drive level is, however, fine. The output saturates at a drive level of about +11 dBm.

● **Input and Output Return Loss**

The measured reference input return loss was 33 dB at 10 MHz, and ≥ 26 dB at all frequencies above 3.8 MHz, as shown in Figure 16. The measured RF output #1 return loss was 47 dB at 10 MHz, , and ≥ 26 dB at all frequencies between 3.4 MHz and 45 MHz, as shown in Figure 17. The RF output return loss is essentially the same for all channels.

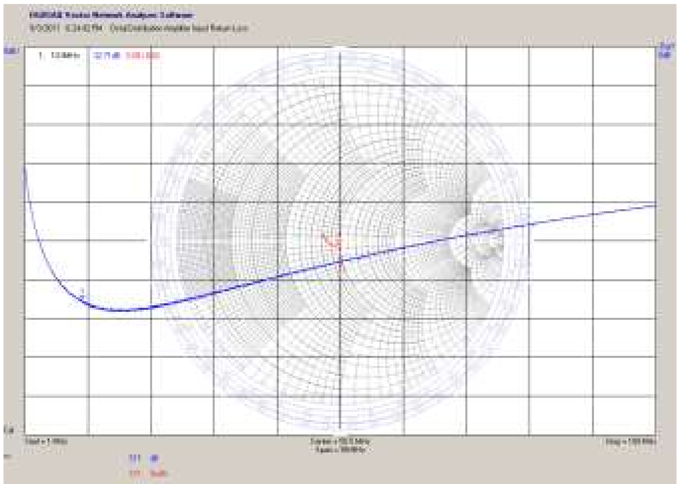


Figure 16. RF Input Return Loss vs Frequency

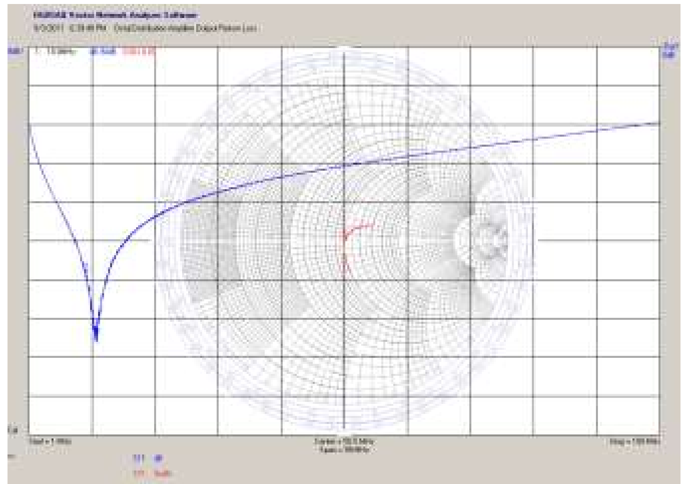


Figure 17. RF O/P #1 Return Loss vs Frequency

- **Forward Gain**

The forward gain of the distribution amplifier is nearly constant at 0 dB between 1 and 100 MHz, as shown in Figure 18. It is +0.24 dB at 10 MHz and within ±0.5 dB between 1 MHz and 44 MHz. The gain is essentially the same for all channels.

- **Reverse Isolation**

The reverse isolation between an output and the input of the distribution amplifier is 57 dB at 10 MHz and greater than 38 dB at any frequency between 1 and 50 MHz, as shown in Figure 19. The reverse isolation is essentially the same for all channels.

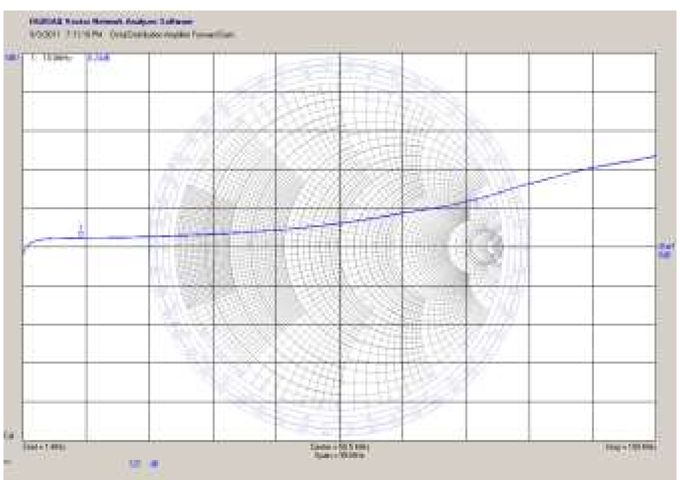


Figure 18. Forward Gain vs Frequency

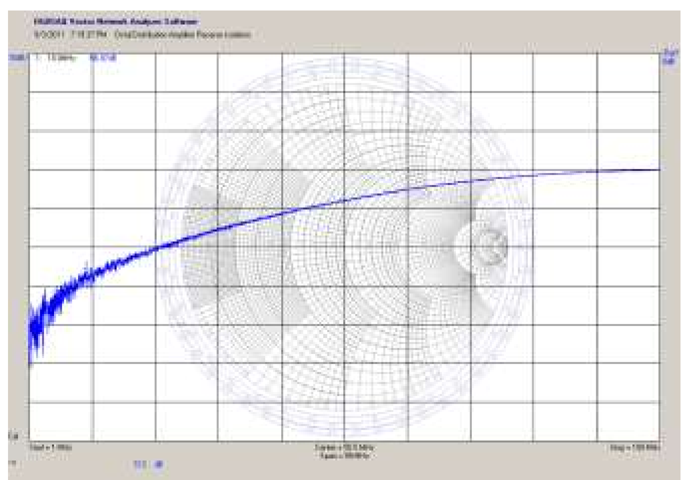


Figure 19. Reverse Isolation vs Frequency

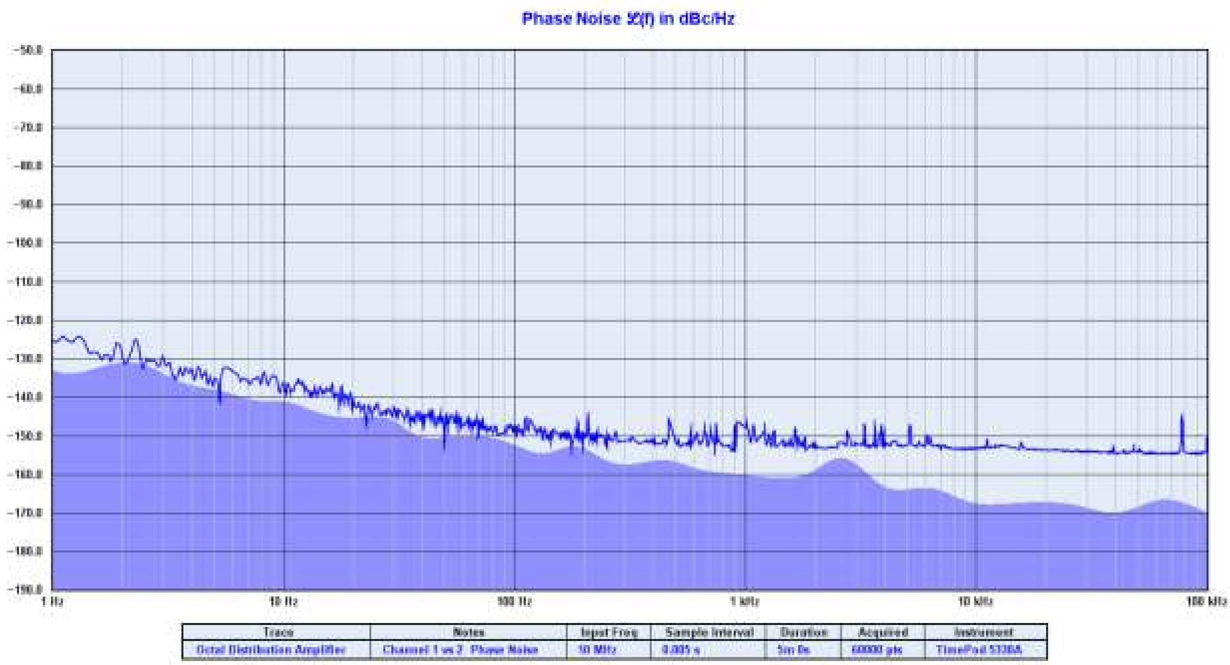
- **Interchannel Isolation**

Interchannel isolation (the isolation between one output and any other output) is an important attribute of a multichannel distribution amplifier. In this design, channels 1-4 and 5-8 are driven from different outputs of a 2-way RF power splitter (see Figure 4) so one might expect better isolation between outputs in different banks than in the same bank. The reverse isolation at 10 MHz from either outputs 2-4 or outputs 6-8 to output #1 was > 75 dB (the noise floor of the measurement). At 100 MHz, the isolation from outputs 2-4 became about 60 dB, while remaining at or below 70 db for outputs 6-8. The actual 10 MHz interchannel isolation may be even better.

Another aspect of this parameter is the amplitude change at one output when the load changes at any other output (e.g., if another output is shorted). No such effect was measured to a resolution of ≤ 0.05 dB.

Phase Noise

The additive phase noise of a typical distribution amplifier channel is shown in Figure 17. While this level of performance isn't exceptionally good, it is quite adequate for its intended purpose to buffer a rubidium oscillator whose phase noise is significantly higher everywhere.



Sideband Frequency Hz	Phase Noise dBc/Hz
1	-125
10	-138
100	-149
1k	-150
10k	-153
100k	-155

Figure 17. Distribution Amp Phase Noise

Spectral Purity

The spectral purity of a typical distribution amplifier channel is shown in Figure 21. All channels are essentially the same, and clean within the resolution of the spectrum analyzer. No spurious components are visible with any frequency span. Power line and other low-level spurs did appear in the phase noise measurement but were suppressed in Figure 17.

- **Harmonic Distortion**

The harmonic distortion of a typical distribution amplifier channel is shown in Figure 22. All channels are essentially the same, and, since the unit is driven from a source having much less distortion, these results are believed to be those of the distribution amplifier. The largest harmonic is the 3rd at a relative level of about -38 dBc.

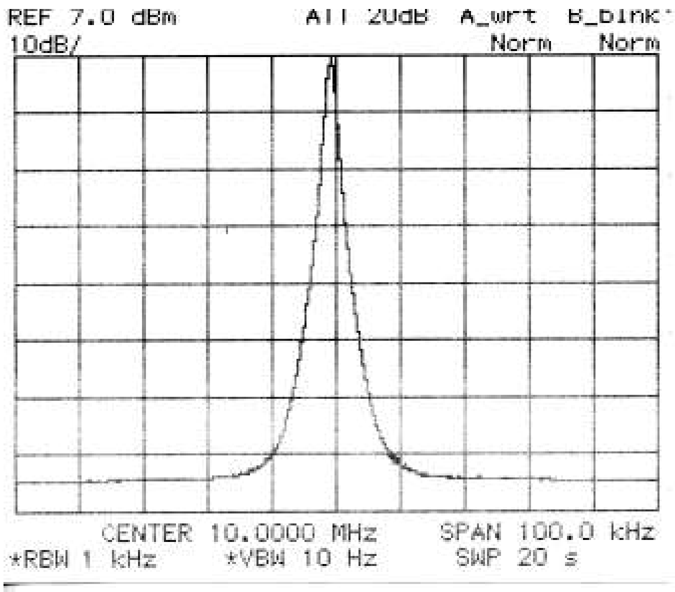


Figure 21. Carrier Spectral Purity

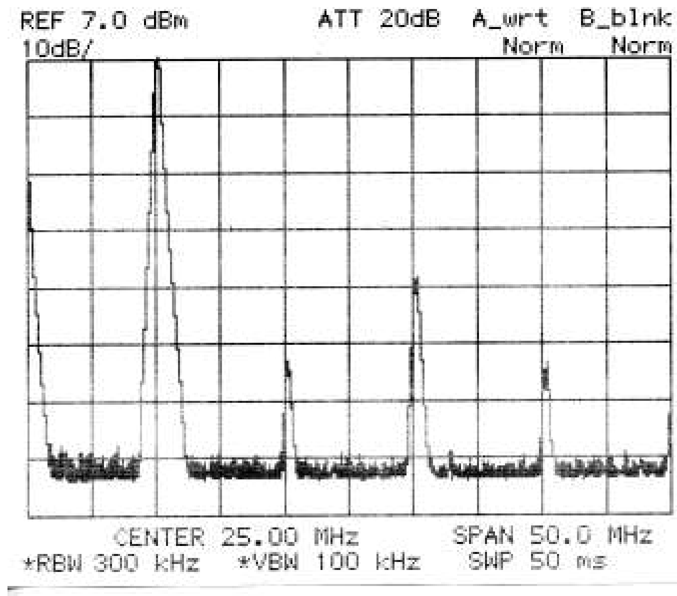


Figure 22. Harmonic Spectrum

- **Power Supply**

The octal 10 MHz distribution amplifier can be powered by the same +24 volt, 1 ampere power supply that runs an Efratom LPRO rubidium oscillator. The input power is applied via a 5.5mm OD x 2.5 mm ID DC power plug. The unit has a series diode in its DC input line that provides reverse polarity protection.

- **DC Power Consumption**

The octal 10 MHz distribution amplifier draws about 30 mA at 24 VDC without RF loads and 47 mA (1.13 watts) fully loaded. Because of the DC/DC converter, the power consumption is fairly constant versus input voltage.

- **Operation**

The power LED will illuminate when +24 VDC power is applied to the unit, and the RF input will illuminate when a signal of ≥ +5 dBm is connected to the rear RF input. The eight RF outputs will then be present at the same level as the input.

- **Applications**

Applications for this instrument include its use to distribute the 10 MHz output of a frequency standard (such as a rubidium oscillator) to other laboratory instruments (e.g., counters, synthesizers, spectrum analyzers and frequency measurement systems). The distribution amplifier is broadband, and can be used at any frequency between 1 and 25 MHz.

Specifications

Preliminary specifications for the Octal 10 MHz distribution amplifier are as follows:

Parameter	Specification	Remarks
RF Input Power	+7 dBm nominal sinewave into 50 Ω	The gain saturates at an input level of about +11 dBm.
RF Input Impedance	50 Ω ±5%	Return Loss ≥ 26 dB.
RF Input Connector	BNC receptacle	Rear panel.
RF Input Level Detector	+5 dBm nominal threshold	Lower drive level is OK.
RF Output Power	+7 dBm nominal sinewave into 50 Ω	Unity gain to all outputs.
Frequency Range	1 to 25 MHz (10 MHz nominal)	Can be used up to 50 MHz.
Waveform	Sinusoidal, no amplitude limiting	Wideband, no low pass filtration.
RF Output Power (each output)	+7 dBm nominal sinewave into 50 Ω	Output voltage is x2 into open circuit. Outputs are short circuit proof.
RF Output Impedance	50 Ω ±5%	Return Loss ≥26 dB.
RF Output Connectors	Eight BNC receptacles	Front panel with ¾ inch spacing.
Interchannel Isolation	≥70 dB	Between any two outputs at 10 MHz.
Output – Input Isolation	≥55 dB	Between any output and RF input.
Phase Noise	SB Freq, Hz — Phase Noise, dBc/Hz 1 — -125 10 — -138 100 — -149 1k — -150 10k — -153 100k — -155	Typical
Operating Temperature	0 to +50 °C	Specs apply at room temperature.
Harmonics	All ≤ -35 dBc	At +7 dBm output into 50 Ω load.
Non-Harmonics	All ≤ -70 dBc	Spurii.
TC of Phase	TBD	
DC Power	+24 VDC nominal at 50 mA DC full load, 30 mA no load.	Input voltage range +18 to +28 VDC.
Size (HxWxD)	1.20" x 6.50" x 8.66"	Excluding connectors and feet. Approximately 1.5" high with feet.
Weight	1.8 lbs. (835 grams)	Excluding cables.
Availability	Not for sale	Design information available at no cost upon request.

References

None

File: An Octal 10 MHz Distribution Amplifier.doc
W.J. Riley
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