Frequency Distribution Design
Basic Module
Document version 4.1

One of the main components of the Frequency distribution is the Distribution Amplifier. In order to design a circuit suitable for this function, you must first of all, locate the main features that are non-negotiable from a technical point of view.

Some features may be:

- AC and DC backup power supply
- High reverse isolation
- High channel to channel isolation
- Low Residual Phase Noise
- High power level capability
- Low cost

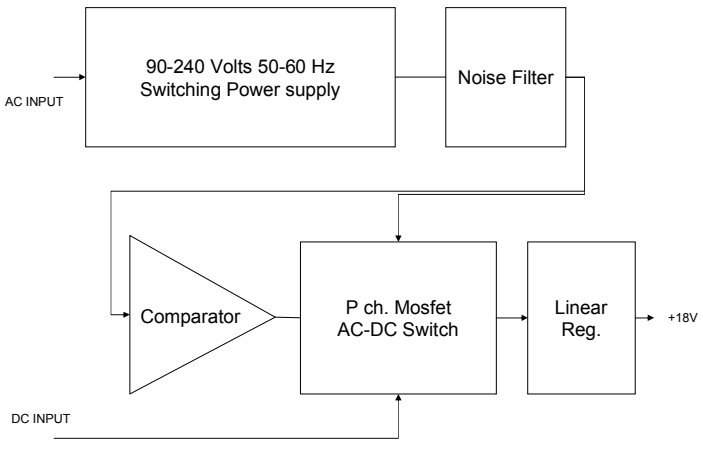
We can then investigate the requirements for the achievement of each of these elements.

AC and DC power supply

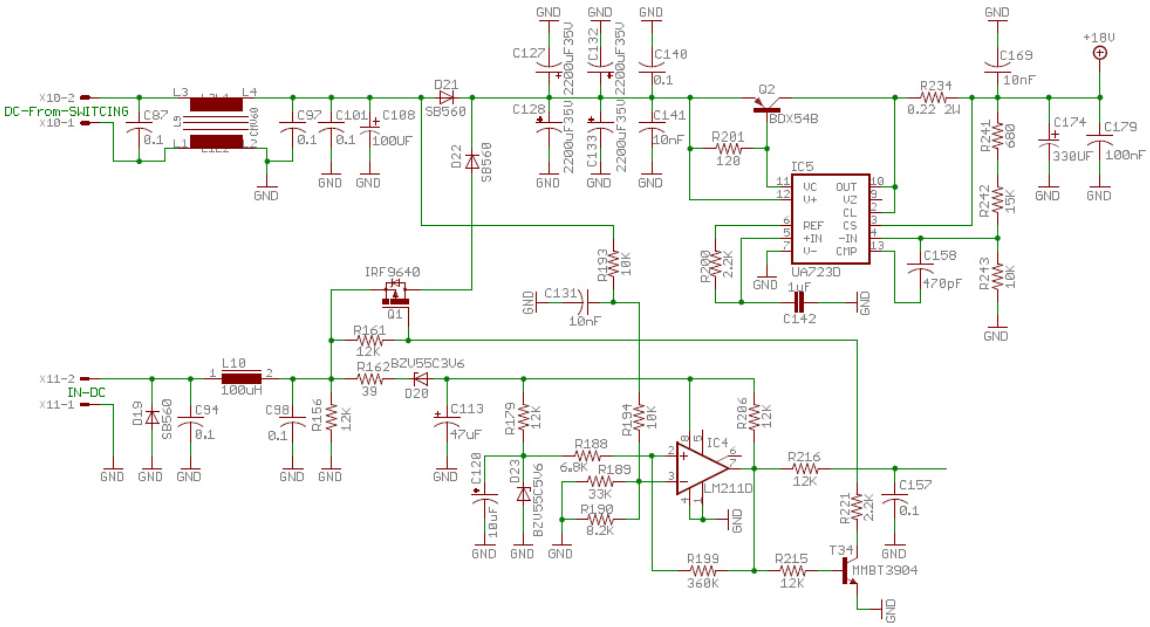
The power sources must be very flexible, for the supposed to be AC suitable for countries that use 60 Hz 115 Volts than for those are using 50 Hz 230 Volts.
For external DC backup power source, the range it might be 24-28 Volts.

Now we have to convert these input voltages in those necessary to power the internal circuitry, taking into account that one of the main requirements is to have internal voltages with very low residual noise to avoid the "modulation" of the frequency standard signals flow in the distribution amplifier.
To simplify the project will be well design an amplifier circuit that uses a single supply voltage and that is few volts below the minimum of the DC backup voltage to be able to use a low noise linear voltage regulators with. Starting from a minimum input of 24V, a voltage of 18 Volts is a good compromise which combines minimum 6 V dropout and an quite high voltage to the output stage for an high power level handling.

The power supply could be so organized:



The switching power supply ensures high efficency and low operating temperatures.



A balanced passive filter can reduce up to 60% of the output spikes level. A fast Power source switch, controlled by a voltage comparator, enables the external DC path when the AC input fail. This particular power management permit a low operating voltage of the AC power supply and consequently a low thermal dissipation of the linear 18 Volts regulator. The linear regulator cleans again from the noise both the external AC and DC power sources.

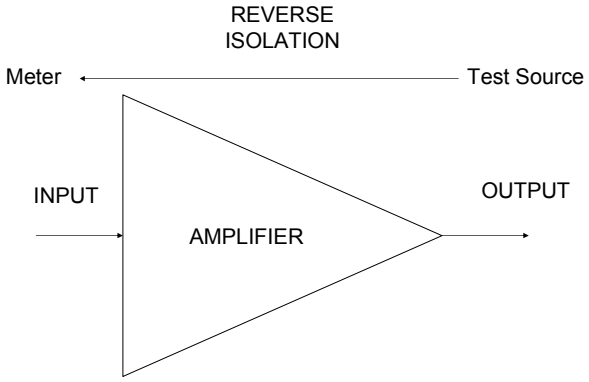
High reverse isolation

The distribution amplifier will be composed of N amplifier/separators equal between them that will have a high input impedance to be put in parallel and form a single common input point and several independent outputs with a 50 Ohm impedance. Further attention will be to isolate the ground output connection from the low frequencies in order to avoid current loops. This happen in complex configurations, they can introduce interferences in signals to be distributed.

Reverse isolation is one of the most important features that must have an amplifier. A great isolation save the source signal from disturbances that may occur when happen an output short-circuit, impedance mismatch or interference source connected to the output of the distribution amplifier.

Some Distribution Amplifier use the Operational Amplifiers because the low cost circuit and only few components needed but this solution has a very low reverse isolation. They are done for commercial video distribution use, is a very low-cost remedy with low performances.

A good Amplifier-Separator configuration is to use two different aplifier stages, a Totem Pole guarantees an excellent reverse isolation followed by a current amplifier that fits the relative high output impedance of the first stage with the output impedance required of 50 Ohm.

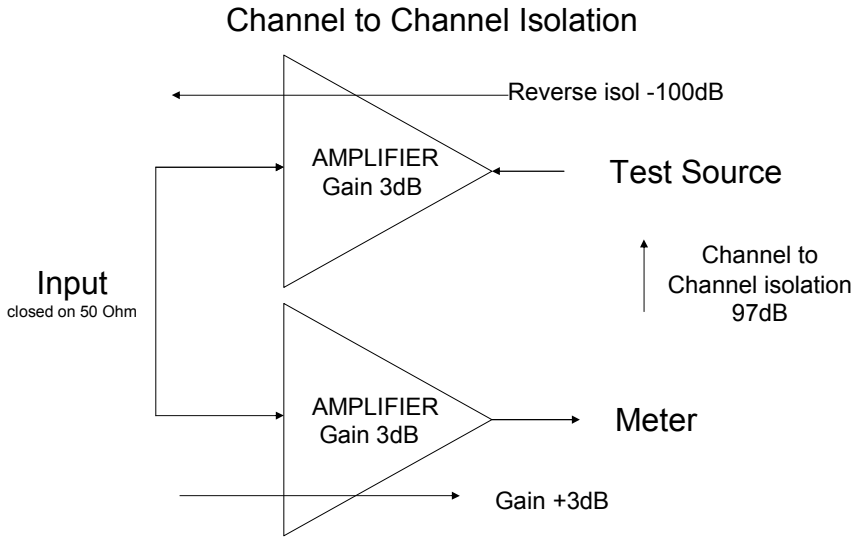


Reverse isolation measurement setup

High channel to channel isolation

Another important parameter is the separation between channels that guarantees isolation between outputs. In case of a short-circuit of an output you must avoid the other outputs are involved in signal variations, then the greater is the separation between outputs, smaller will be involved other channels.

The channel to channel separation is tipically lower than the reverse isolation. To better understand you can see below an example of calculating where the reverse isolation value have to be added algebrically to the direct gain of the second amplifier.



There may be other factors which influence the separation between channels, such as the capacitive couplings due to the proximity of the output connectors and the same components of the adiacent amplifiers, especially if

not shielded between them. A smd low profile realization, help to limit the coupling between the channels.

Low Residual or Additive Phase noise

In signal processing phase noise is the frequency domain representation of rapid, short-term, random fluctuations in the phase of a waveform, caused by time domain instabilities. All real oscillators and the related components like a distribution amplifier have phase and aplitide modulated noise components. The phase noise components spread the power of a signal to adjacent frequencies, resulting in noise sidebands.

When we talk of this added noise it is referred to as Additive or Residual Phase Noise, a noise component that is added to the signal that passes through to the quadrupole or is generated by an oscillator.

The Residual or Additive Phase noise in oscillator or amplifiers comes from two different sources; additive voltage fluctuations and direct parameter modulation. Additive noise is generally caused by thermally-generated voltage fluctuations that are added to the carrier signal and result in phase and amplitude fluctuations. This type of noise shows up as the nise floor at large frequency offsets from the carrier(short Tau values) and is flat (white) phase noise. The second type is modulation noise. The most well known si flicker (1/f) noise. This is caused by direct phase or frequency fluctuations in the resonant device or by phase fluctuations in other electronic components.

A distribution amplifier must be able to handle an input signal with the addition of minimum phase noise. Only a careful design and selected components can ensure a low Residual Phase Noise.

High power level capability

Making of investigations about the market concerning time and frequency equipment, you can locate more parameters used in connections between equipment. One of these parameters is for a standard power level that tipically is +13dBm.

Taking this figure, we have to consider a project that is able to have an operating margin greater than this value of approximately 3 or 4dBm. This focus is essential to avoid saturating the amplifier and produce harmonic distortion that would compromise the integrity of the signal.

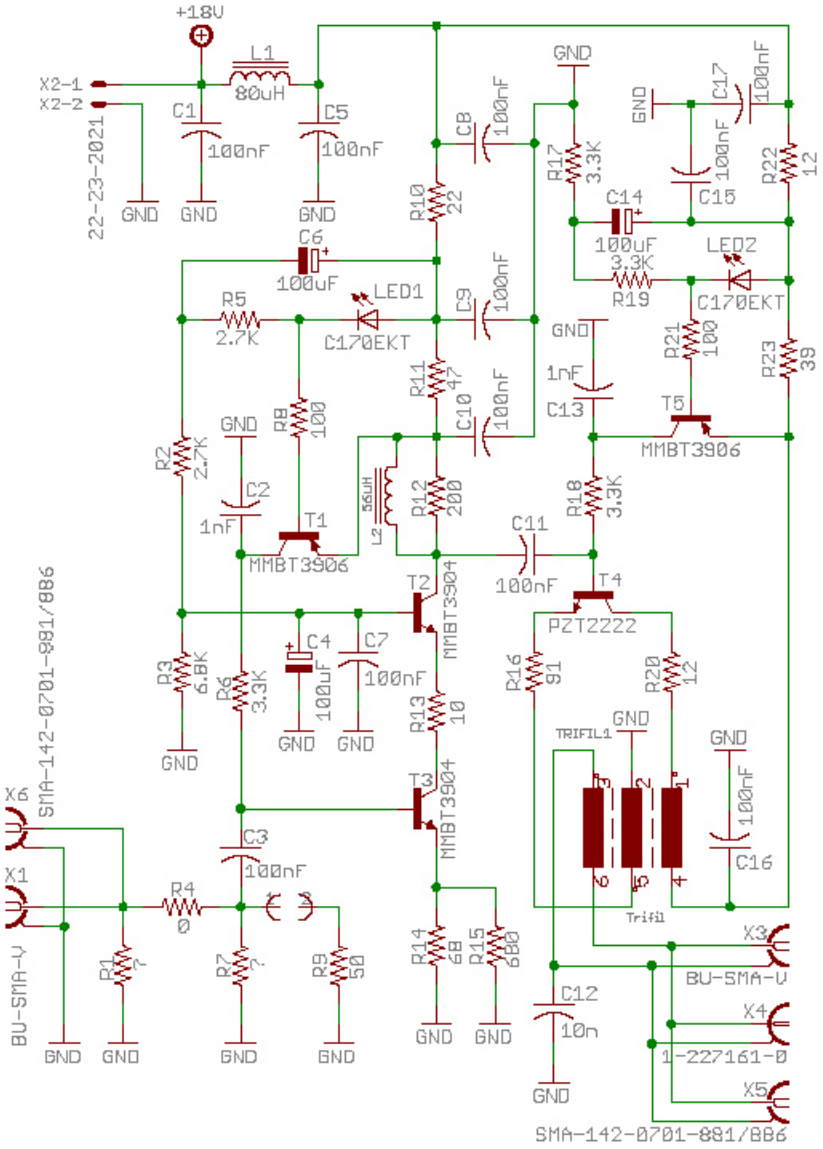
Low Cost

A typical distribution amplifier is configured to have 12 outputs. This involves a large number of components, therefore a production and selling cost high. Is therefore very important to find the right balance between performance, reliability and a moderate cost. This objective have to be treated during both the project and engineering phases.

The proposed solution uses components very common then, beyond that of easy availability, also cheap. As with all commercial products , the quantities produced seriously affect the cost of the single piece.

The Basic Module

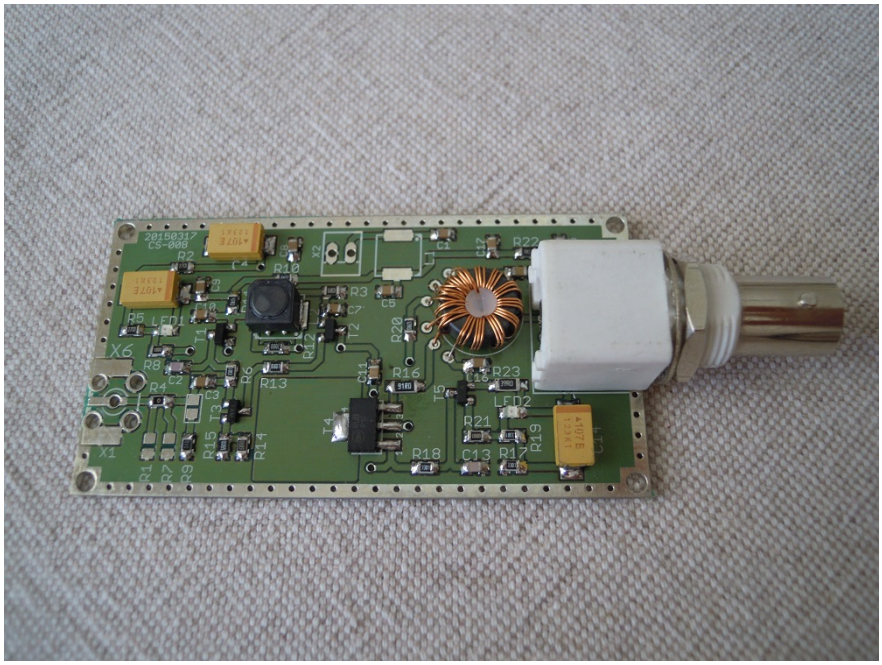
To achieve a result that met all the requirements listed previously wanted to make a simple circuit and adaptable to most common requests. The result, after three years of development and implementation is described here.



Schematic

note:

- the parallel input and output connectors are only for the pcb multiple connector project.
- The input attenuator R1,4,7 and R9 are used for the input configuration.
- The resistors R14/15 are used to set the gain. As shown the gain is 3dB on 50 Ohm input (R9 connected by the jumper).



Single Channel amplifier

The Basic Module is a single channel amplifier with the following thechnical specification:

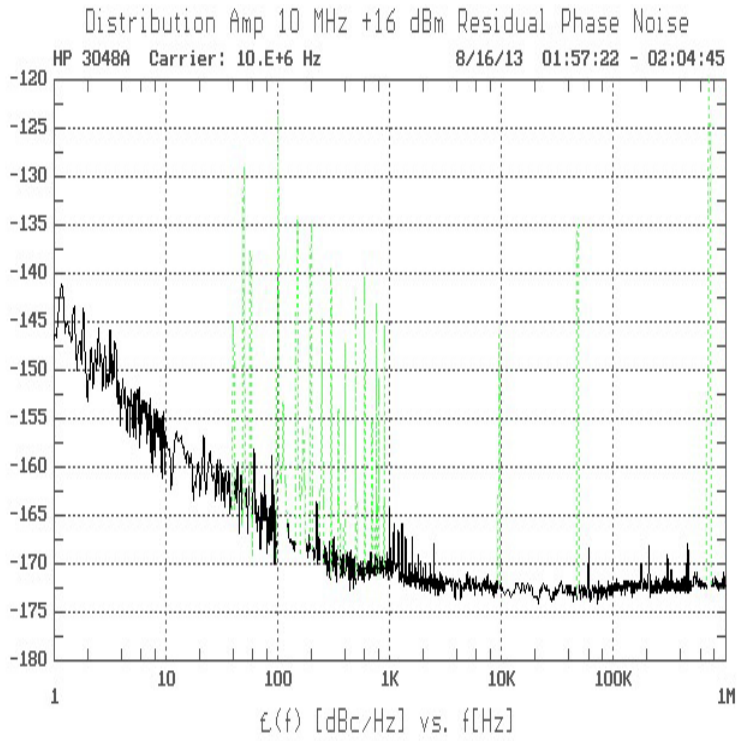
Zin: settable 50 Ohm to 3k Ohm
Zout: 50 Ohm low frequency ground loop isolation
Gain: 0 to 10dB settable by a resistor
Reverse isolation: 100dB (typical 107dB)
Input connector: wire or sma
Output connector: wire, sma or BNC

Residual Phase noise:
1Hz   -145 dBc/Hz
10Hz   -158 dBc/Hz
100Hz -166 dBc/Hz
1kHz   -170 dBc/Hz
10kHz -170 dBc/Hz
100kHz -170 dBc/Hz

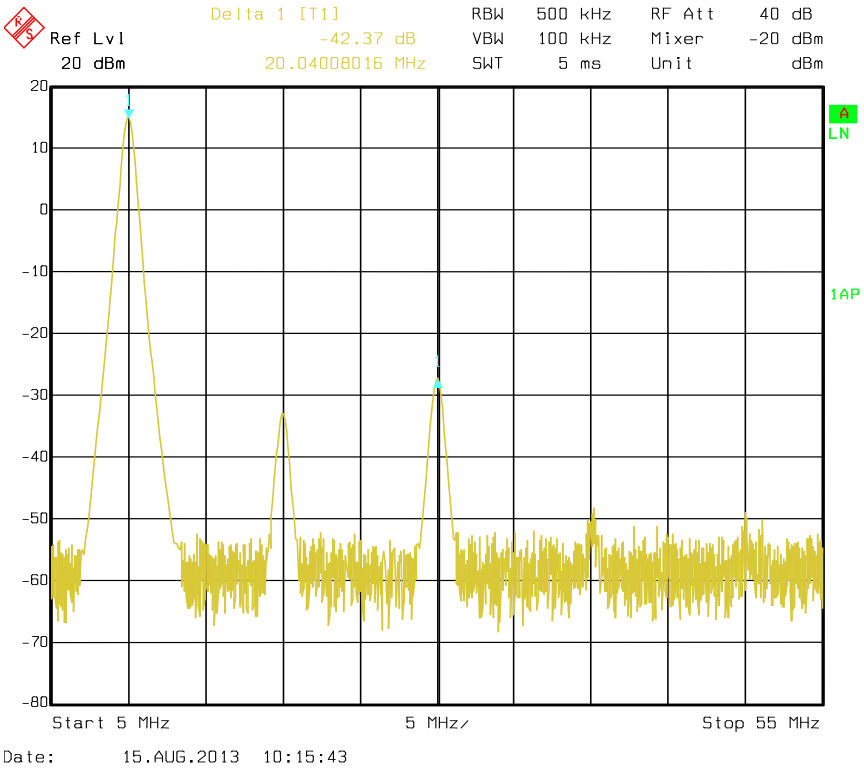
3rd Harmonic distortion
Po +15dBm -42dBc
Po +16dBm -39dBc
Po +17dBm -36dBc
Po +18dBm -32dBc

Pout: +17 dBm @ 1dB compression.
Power supply: 18V 70mA max.

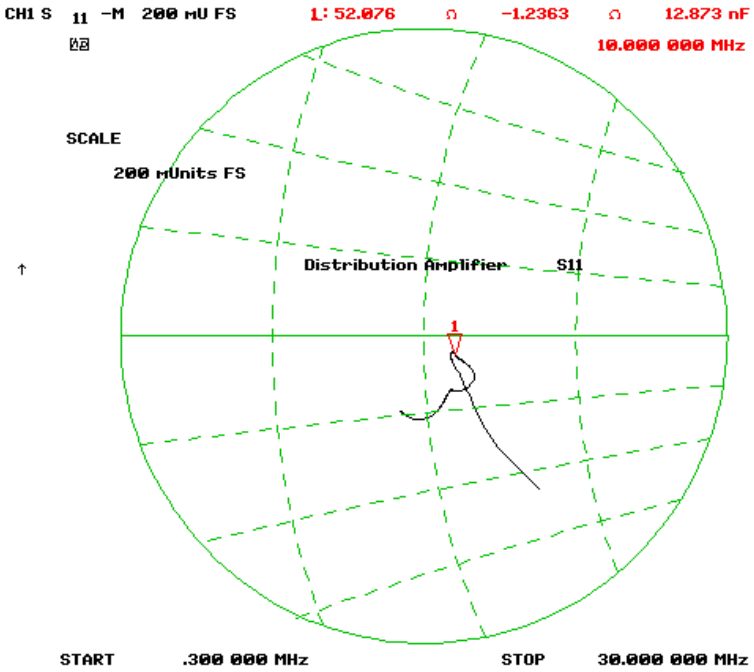
The output can drive load from 50 to infinite Ohm without significative sinewave distortion.



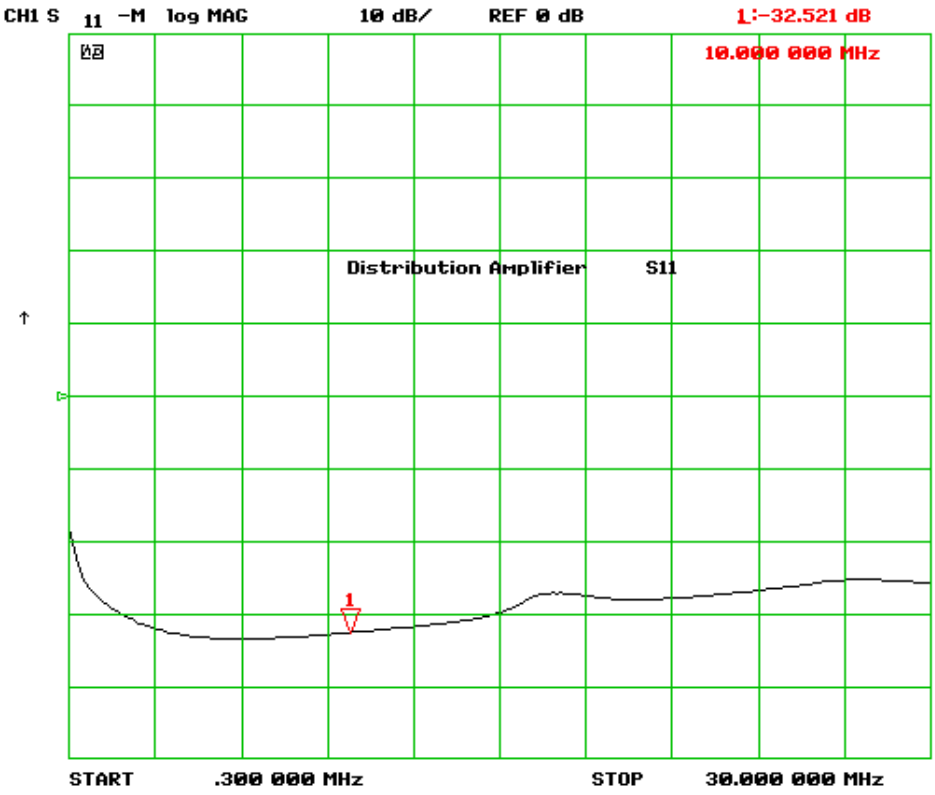
Residual Phase Noise measured in a 50 Ohm input configuration



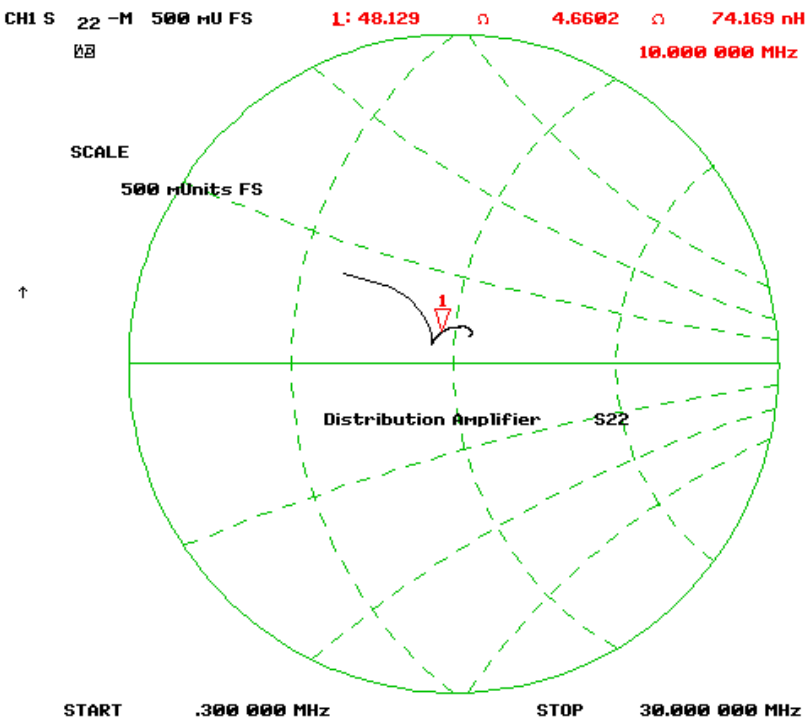
+15dBm Harmonic Distortion measured with a 50 Ohm input configuration



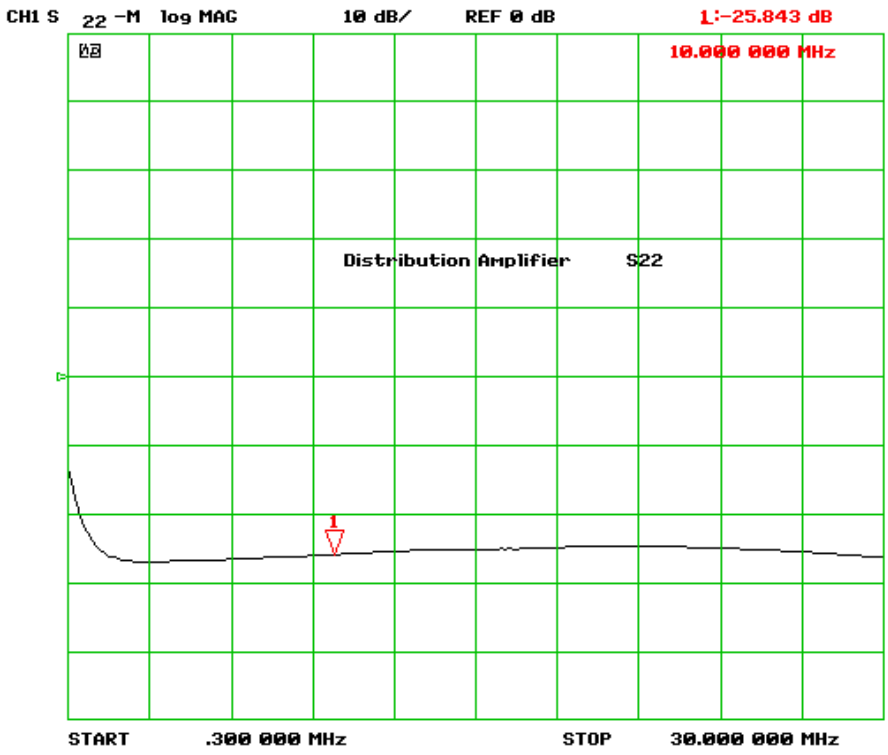
10MHz S11 input impedance



10MHz input return loss



10MHz S22 output impedance



10MHz output return loss

An assessment was made in the Wab comparing the Basic Module specifications from other products or published projects.

Preliminary technical evaluation												
Brand	Model	1Hz	10Hz	100Hz	1kHz	10kHz	100kHz	max dBm out @1dB	dB rev. isolation	dB crosstalk	Harmonic dist. dBc @+13	Note
Brandywine communications	FDU 160I	-132	-142	-155	-163	-163	na	+13	na	-80	40	linear
Stanford Research System	FS730	-120	-135	-155	-157	-158	na	+13	>100dB	na	na	limiter
Quartzlock	A5-8	-140	-150	-160	-165	na	-168	+13	-110	-90	38	linear
Timetech	10273	-141	-148	-152	-153	-153	na	+13	140	-90	53	linear
W.J.Riley	octal d.a.	-125	-138	-149	-150	-152	-155	+7	55	-70	35 @Po +7	linear
Wenzel	LNDA	na	-150	na	na	na	na	+13	na	-50	30	linear
Spectral Dynamics	DA100	na	-156	-162	na	-163	na	+15	85	-48	40	linear
Novus	ND0100-R	-120	-130	-140	-145	-147	-148	na	na	na	30	linear
Symmetricom	5087B	-110	-123	-128	-144	-150	na	+22.5	-100	-104	40	agc
FEMTO ST institute	na	-135	-150	-158	-162	-163	-165	na	na	na	41	linear
NIST new d.a.	na	-152	-162	-168	-170	-170	-171	+13	-144	-125	45	linear
Basic Module	na	-145	-158	-166	-170	-170	-170	+17	-107	-97	45	linear
TNS-BUF	TNS-BUF	-140	-150	-158	-165	-173	-175	na	104-111	na	na	linear
not our target												
first as performance												
second as perf.												

This High Performance Basic Module due his high input impedance can be stacked up to twelve amplifiers to combine a single input multiple output distribution amplifier. The input impedance will be arranged with the help of a resistor on each amplifier so that it will be equal to the 50 ohms standard.

The gain of the distribution amplifiers, typically, is equal to 1, though it may be interesting that is settled to +3 dB in order to amplify any input source a little lacking. If you want the unity gain, it will be very easy to restore it by inserting a 3dB pad on input connector.

The two stage amplifier, totem pole and current amplifier can guarantee more than 100dB (60+40)of reverse isolation.

To increase the thermal dissipation capacity of the output transistor was increased the copper thickness of the PCB. In this way, also in consideration of 12 aplifiers fitted in a confined space, is possible to dissipate into the metal frame much of the generated heat.

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Bruce Griffith for the thecnical support
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Reference:

HP AN 358-12 Simplify frequency stability measurements with a built-in Allan variance analysis.