Distribution Amplifiers for the Ham Shack

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Abstract
This paper introduces applications for distribution amplifiers in the ham shack, and provides some simple designs and advice.

Introduction
Those working in the telecommunications and audio/video industries will be familiar with the use of distribution amplifiers (DA), but for many their application to the shack is not so obvious. In this short article I hope to lift some of the mist!

What is a DA?
A DA is an amplifier designed to provide multiple copies of the input via several output ports – common types give 4, 6 or even more outputs. Depending on the design it may also provide filtering, transformer isolation and gain adjustment. Some of the simplest homebuilt DA's are based around digital buffer IC's such as the 74HC04, often using several gates in parallel to meet the output drive requirements into 50 ohm loads – I will refer to these as 'digital' DA's. Analogue DA's may be based around transistors, MMIC's or video IC's – Maxim used to make some very good video amplifiers which were effectively a 'DA in a tin' – regrettably these are obsolete!

Common Applications
The most common application in the last few years has become that of providing the necessary number of 10MHz outputs from the shack reference source (GPSDO or OCXO). With the explosion in availability of good surplus sources (eg HPZ3801, Trimble Thunderbolts etc), the standard has become to use this reference to frequency lock your test equipment and any microwave and VHF transverter LO's, thus removing one of the uncontrolled variables for the equation.

However, other applications also arise, again thanks in part to new technology – in this case software defined radio (SDR). Although there are an increasing number of SDR transceivers available, there are also many Rx only models, such as the excellent Softrocks and SDR-IQ/14s etc. Many operators want to use these in parallel with traditional rigs to have the advantage of a visual output as well as the audio – this is particularly true in microwave and EME work. Here again, a DA can provide the solution.

10MHz distribution
Most of the DA's available surplus and via 'amateur' sources (see websearch) are capable of providing 10MHz distribution. They are also easy to homebrew on stripboard etc, using 74HC04's or analogue circuitry. Depending on what you are going to use it for, and the output quality of your source you may need to provide filtering and isolation too. Some issues that may need consideration for your application are:

> **OCXO Output Spectrum** –the OCXO can be considered as essentially a good quality, low noise crystal oscillator, so it ought to be giving a good sine wave output, with minimal harmonics? Well maybe, but often there is considerable harmonic content, especially odd. Typical levels can be -20dBc at the 3rd harmonic, decreasing with frequency. This may not be a problem, depending on what you are driving with it.

Analogue and 'Digital' DA's – Some designs of DA, including those based on video techniques are analogue, and effectively run in Class A – being therefore relatively power hungry, but faithfully reproducing at the output what is presented at the input – harmonics and all, if there is no filtering in the DA. The other class of DA's (mostly home constructed) are based around digital buffers, such as the 74HC04, which is why I have referred to them as 'digital'. They will effectively switch at the lowest input frequency (10MHz), and provide a 10MHz square wave on each output – which, as we know contains the higher order odd harmonics too. So even if your input from your OCXO is clean, a digital DA will have a harmonic rich output.

10MHz inputs – neither of the two previous situations necessarily represent problems by themselves. The problem is usually created in the equipment that is being driven, but action at the earlier stages is required to solve it. Some test equipment especially is designed to operate from a clean 10MHz reference, and does not like to see significant levels of harmonics present. Thus the output of a digital DA will always give it a problem, and the output of an analogue DA may if the input source is not clean.

Getting it sorted
Fortunately, the answer to all of these issues can be found cheaply – old PC network cards! Now that most motherboards have LAN capabilities built in, it's common to find boxes of old PC cards underneath the stands of some surplus traders – a few moments digging can provide a set of useful components for a very small outlay. See [4] for further information on using the filters and isolation transformers from these cards.

Using the filters and transformers
The recovered packages can be mounted on small pieces of board with short coax leads attached to connectors mounted on the screening box. If these are made up as individual units (a filter or a transformer) they can be used where needed in the system, with the other items in the package ignored (or left for later use in case of failures).

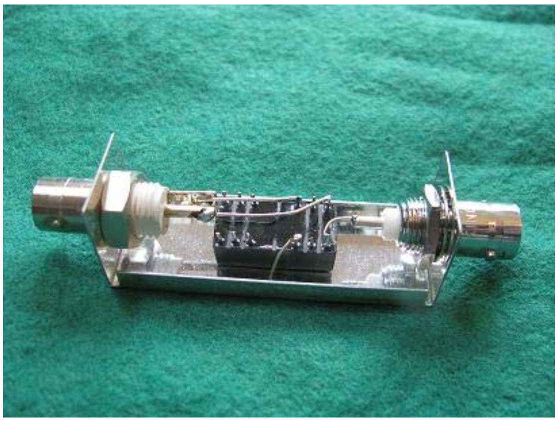

Fig 1 – A recovered filter assembled in a small tin-plate enclosure, with insulated output connector

Fig 1 shows a very simple implementation of an isolating filter, using the Tx portion of a recovered package. The 55 x 20 x 20mm enclosure is one of O Schubert's range, and is available pre-punched for BNC connectors at each end – ideal for making up RF attenuators, filters and bias tees. The frequency response shown in Fig 2 is the measured response of this filter. The isolating BNC connector used is not one recovered from a card, since these will not fit into the small enclosure.

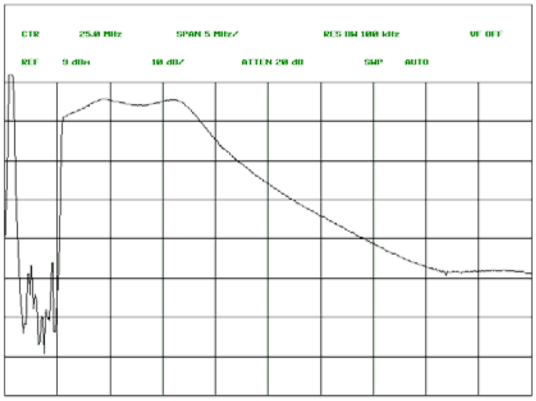

Fig 2 – Frequency response of the Tx filter over the range 5 to 50MHz

Higher Frequency Applications

For SDR inputs and other applications away from 10MHz, then DA's that have internal filtering are not so useful – we may want to work at 10m, 2m or even 23cm for the split. Usually a two way split is needed to take the Rx line into the 'traditional' rig and the SDR – any unused outputs on the DA must be correctly terminated. Fig 3 shows the arrangement used in my own station, to give me SDR performance on 23cm EME, in addition to full Tx/Rx capabilities from the main rig. Note that no Tx muting is required on the SDR side of the chain.

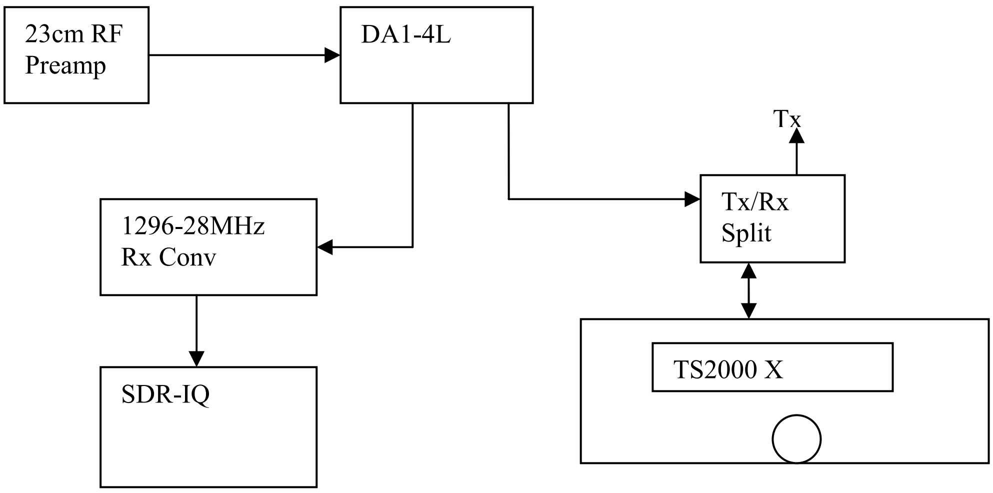

Fig 3 – Using a DA to provide parallel Rx paths

This arrangement can be used at any suitable frequency – the only precaution needed is to ensure that the Tx and Rx lines from the main transceiver are separate!

A 2 way DA design

A simple two way design, with a response to over 2GHz is shown at Fig 4, with a suggested PCB component layout at Fig 5. In case of any difficulties, higher quality reproductions of these, and the PCB track layout, can be obtained from the author on request [5]. If demand is sufficient, commercially produced PCB's could be made available

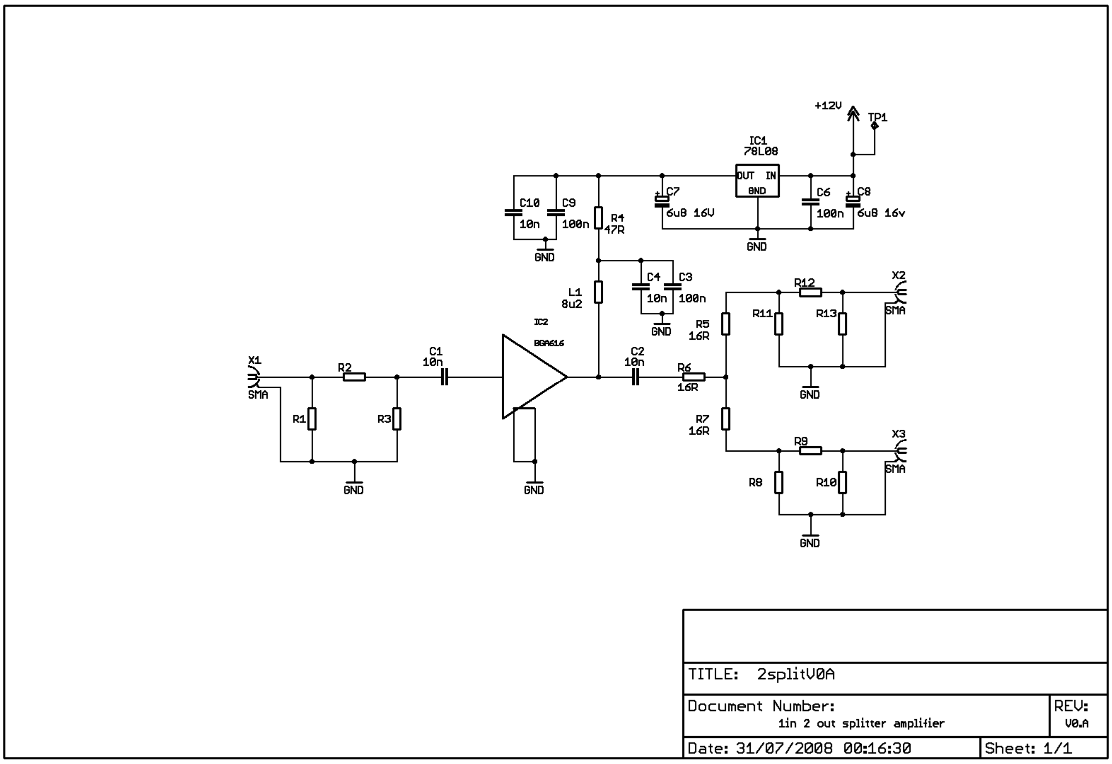

Fig 4 – Schematic of 2 way DA

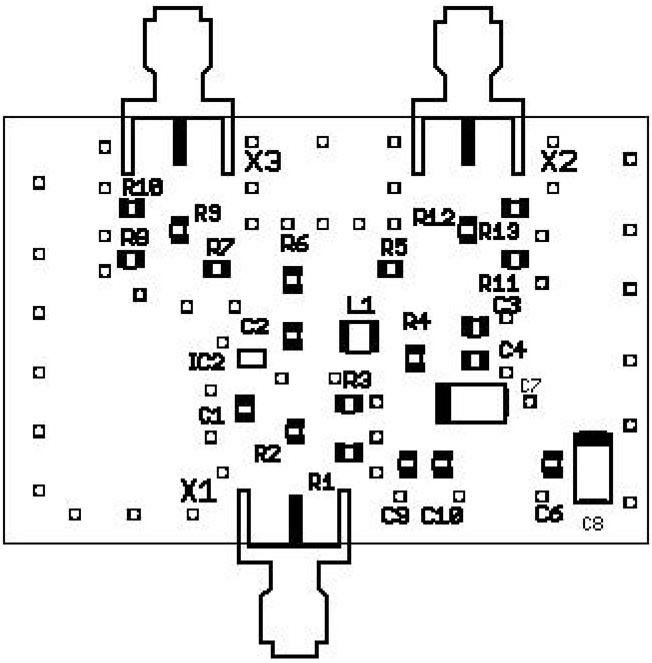

Fig 5 – Component layout for 2 way DA / splitter

DA1-2 Distribution Amplifier Operation Overview

The DA is designed to accept an input signal at a nominal +0dBm level maximum. This level should not be exceeded into the BGA616, as there is a risk of overdriving it and producing unnecessary non-linearity and harmonics of the input signal. If your input is above this level, insert an appropriate attenuator, either outboard of the unit, or fabricated from 3 0805 size resistors on the pads provided.

The input signal is amplified in the Siemens BGA616 MMIC amplifier, then resistively split into two. Each path has provision for an output attenuator. The PCB layout is designed to suit a small tin-plate housing to ensure good grounding at all frequencies, as well as RF shielding. SMA connectors are recommended.

Circuit Description

R1 R2 and R3 form the input attenuator, however, they also provide a location where a further MMIC could be grafted in if required – this may be useful if the input signal is particularly low in level.

The output of the amplifier is split equally by R5, 6 and 7.

Each output has an output attenuator available on the PCB. For operation with no attenuation, remember to short out the positions of R9 and R12.

A 78L08 TO92 style regulator provides the supply for the MMIC – total current drawn is approx 80mA.

Performance

Table 1 below shows the measured performance at 10MHz

Input Frequency	10	MHz
Input Level	+0	dBm (max)
Output Frequency	10	MHz
Output Level	+12.5	dBm per channel (0dB Atten)
Supply Voltage	10 – 15	V
Supply Current	80	mA @ 13vdc typ

Table 1 – 2 way DA performance at 10MHz

The high frequency response is also extremely good, since there are no frequency-shaping components in the circuit, and attention was paid in the layout to equal path lengths on both sides of the split, to maintain as good a performance as possible. Fig 6 shows the response of the DA above 2GHz, demonstrating that it has useful gain up through the 9cm band. Note that these measurements were made with 0dB attenuation in place, before or after the split, so represent the maximum attainable performance. In any specific application, the gain levels should be attenuated back to meet the requirement, and avoid the unnecessary risk of generation of harmonics and spurii. At 2m for example, with 0dBm in, and 0dB attenuation the output level is approx +14dBm per channel.

Limitations

This simple design has many attractions and uses, but it does also have some limitations – the isolation between the outputs is limited to that provided by the resistive splitter in the worst case – ie 3dB typ. Any attenuation placed in either output will increase this figure, but users must be aware of this – the implication in uses such as that described above, is that if either receive path were outputting spurious signals at their input, then these signals would be presented to the other Rx with minimal attenuation. This could be a cause of unexpected problems in the receive chain.

DA's can also be used in Tx chains, for example to split LO drive between modules, or even (with one output terminated) to find that 'missing' 3 or 6dB in the power levels!

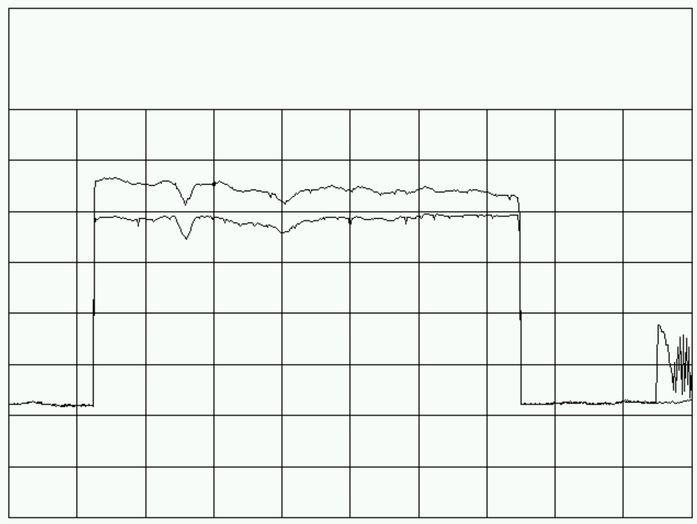

Fig 6 – 2 way DA response 2 – 3.5GHz. Lower trace is reference (0dB gain)

A four way DA

A more complex 4 way DA, but based on the same principles, is shown at Fig 7.
It has some advantages over the 2 way design - the excess attenuation of the double split arrangement necessitated moving the gain to the output side of the split – thus the isolation between the output ports is considerably improved – in the order of 30dB. Thus the overall maximum gain is a bit lower, and the frequency response is useful up to 2GHz. This design is available as a kit (DA1-4L) for normal DA applications, and also as DA1-4G for distribution of GPS antenna signals to multiple GPS receivers – in this case additional power feeding components are included to supply the 5v for the active GPS antenna. Kits and PCB's are available, and a full Technical Manual is already on the website [1].

As with the 2 way DA PCB, the design is laid out to fit a standard size tin-plate box for grounding and shielding. Either SMA or BNC connectors can be used to suit the other station equipment. Fig 8 shows a built DA1-4L, using BNC connectors.

In both the 2 way and 4 way designs on my PCB's there are various options or 'tricks' which can be used. Both have an input attenuator position which can be optionally used for a single stage Pi LPF constructed of 0805 size SMD components. Similarly, the output attenuator positions can be usurped to become filters. It is also possible on both designs to 'graft in' an extra gain stage at the input, for really low level signal applications, if more gain needed in the DA. However, be wary of over-providing gain!

In all DA applications, unused output ports should be terminated in the characteristic impedance, unless specifically stated by the manufacturer that this is not necessary.

Performance

With useful gain up to nearly 2GHz, and carefully equalised line lengths through the unit, the phase performance of the DA1-4 is very good – at 10MHz, it appears to be rather less than 3° difference between any of the outputs. This increases with frequency, but even at 1296MHz it is less than 10°.

Input Frequency[1]	10	MHz
Input Level	+0	dBm (Max i/p +5dBm)
Output Frequency	10	MHz
Output Level[2]	+5	dBm per channel (0dB Atten)
Gain Variation between channels	<4%	At 10MHz
Phase variation between channels	<±3°	At 10MHz
Inter-channel Isolation	>25	dB typ. at 10MHz
Max output	+10	dBm (recommended)
Supply Voltage	12 – 15	V
Supply Current	330	mA @ 13.4vdc

Table 2 – DA1-4L Performance at 10MHz

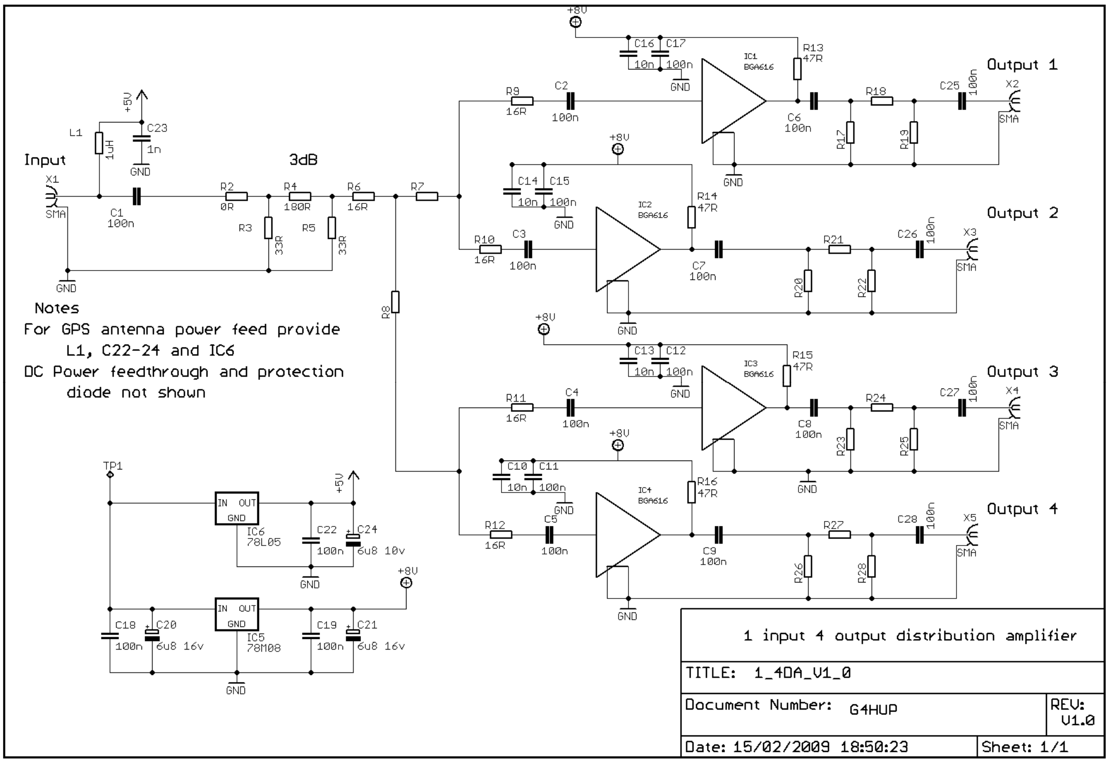

Fig 7 – 4 way DA schematic diagram

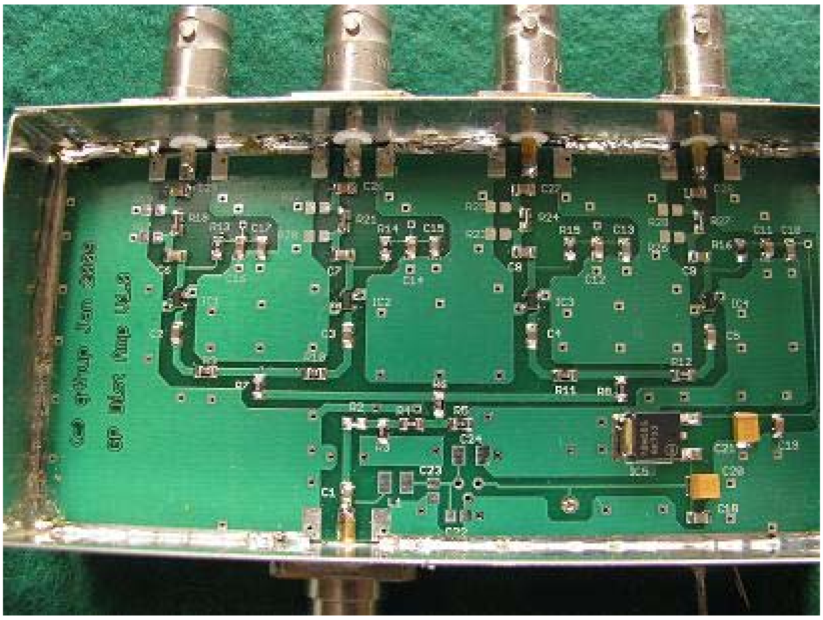

Fig 8 – Internal view of DA1-4L

Summary

In showing how Distribution Amplifiers can form useful accessories in the ham shack some issues about 10MHz distribution have been discussed, and two simple DA designs introduced. Wider applications of DA's at other frequencies have also been shown to demonstrate the utility of these devices.

Websearch

[1] http://g4hup.com/DA/DA1_4.htm

[2] http://www.tapr.org/kits_tadd-1.html

[3] http://www.downeastmicrowave.com/ DEM 10-4

[4] http://g4hup.com/DA/DA1_4.htm

[5] http://g4hup.com or g4hup@btinternet.com