Various circuit architectures for distribution amplifiers

This guide refers to the four schematic diagrams on the following page. It addresses distribution amplifier architectures for frequency standard outputs from 1 to 10 MHz at the customary level of 1 Vrms (+13 dBm).

1. Individual output amplifiers

This architecture uses amplifiers with (i) high input impedance (at least 50 ohms x number of channels) and (ii) a voltage gain of 2. The amplifier inputs are paralleled, then a termination resistor is added in parallel to make the overall input impedance 50 ohms. Each amplifier feeds one output. If the amplifiers do not inherently have 50 ohm output impedance, back-termination resistors are added in series to make them 50 ohm sources.

2. Amplifier with build-out resistors

This architecture uses one amplifier with (i) very low output impedance and (ii) a voltage gain of 2. The amplifier drives multiple, 50 ohm back-termination resistors, one for each output.

Note that driving a 50 ohm load to the customary reference level of 1 Vrms (+13 dBm) requires peak currents of +/- 30 mA. Thus, a 12-output DA would require an amplifier capable of delivering +/- 360 mA. This practical consideration often leads to a hybrid architecture, in which several amplifiers with very low output impedance each drive several back-terminated outputs -- so instead of one amplifier per output, they use one amplifier for every 3 or 4 outputs. Both of the designs included here (AD8010 and LME49713) use this hybrid architecture, although one could use one op-amp per output if desired.

3. Amplifier with hybrid power splitter

A series of 3 dB hybrid power splitters can be used to provide multiple outputs from the input feed. Since each split reduces the output level by 3 dB, the string of splitters is usually preceded by an amplifier with a 50 ohm output that makes up the lost level. A 2-way splitter requires a 3 dB amplifier, a 4-way splitter requires a 6 dB amplifier, an 8-way splitter requires a 9 dB amplifier, and so on. Thus, to drive 50 ohm loads to the customary reference level of 1 Vrms (+13 dBm), the amplifier must be capable of driving a 50 ohm load to +16 dBm (2-way splitter), +19 dBm (4-way splitter), +22 dBm (8-way splitter), and so on. This practical consideration generally limits designs using this architecture to 8 or fewer outputs.

Unused outputs should be terminated with 50 ohm terminators to preserve isolation. Similarly, outputs terminated in an impedance higher than 50 ohms should have 50 ohm feedthrough terminators installed at the load end of the driving cable.

4. Logic gates with or without output filters

An interesting approach is to use logic gates to fan out the input signal to multiple drivers, which then drive the outputs. Each driver is typically several (often 3) "HC" series CMOS inverters or non-inverting buffers in parallel, although line drivers and other sturdy gates are also often used (limited only by the imagination of the designer). If gates are paralleled, they should all be on the same chip. The logic-level square wave can be distributed directly, or a simple LC filter can be used to convert it to a sine wave (an L-C-L "Tee" filter of modest Q is often sufficient).

This technique is mainly used when the source is a logic-level square wave to begin with. If the source is a sine wave it must be converted to a square wave, which risks introducing jitter and phase noise. If an L-C output filter is used to convert the square-wave logic outputs to sine wave, it also has the potential to add phase noise due to the temperature sensitivity of the components (particularly, the inductors). However, distributing square waves is generally disfavored because (i) the harmonics are prone to radiation, creating undesired RF noise in the laboratory (especially unwelcome when radios are being operated in the vicinity), and (ii) properly terminating cables carrying logic-level square waves raises additional issues.

A note about back-termination:

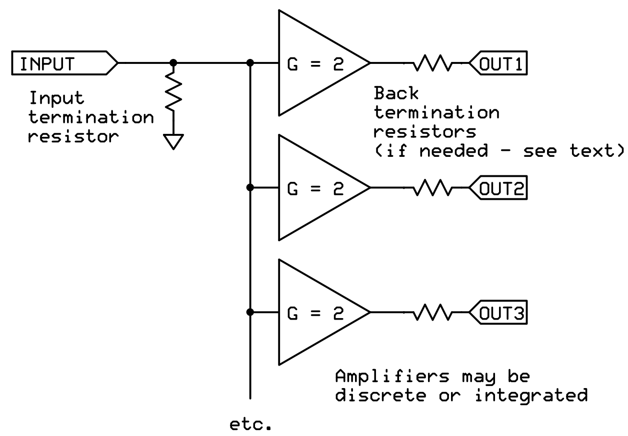
When signals are sent over transmission lines (e.g., coaxial cables), undesirable reflections are minimized when both the source and the load terminate the cable in its characteristic impedance (typically, 50 ohms in the laboratory environment).

When designing and building a general purpose distribution amplifier, we have no idea how the load end of the coax will be terminated. In this case, it is still best if the source presents a resistive, 50-ohm termination to the cable. That way, even if the load end of the cable is mis-terminated, the ensuing reflections are absorbed in the source termination and do not circulate on the cable. This can be done by either (i) using an amplifier designed with an intrinsic 50 ohm output impedance, or (ii) using an amplifier with a lower output impedance and adding a series resistor to bring the output impedance up to 50 ohms. If the amplifier has a near-zero output impedance, this “back-termination” resistor will be approximately 50 ohms.

In either case, the open-circuit output voltage of the DA must be twice the nominal output level (i.e., 2 Vrms in a standard 1 Vrms laboratory environment). This means the voltage seen by a 50 ohm load is attenuated 6 dB from the open-circuit output voltage, and is why DAs are designed with 6 dB of gain.

However, if the load impedance is significantly higher than 50 ohms, it will see a voltage greater than the 1 Vrms standard voltage the DA puts out into a 50 ohm load (up to a maximum of 2 Vrms, if the load impedance approaches infinity). This may be of practical importance in the laboratory. Many devices, particularly laboratory instruments, have frequency reference inputs that are about 1k ohm, NOT 50 ohm. If the instrument being fed cannot tolerate the higher level, one must use a "50 ohm feedthrough terminator" at the load end of the cable to reduce the level to 1 Vrms. (Alternatively, a standard 50 ohm in-line pad can be used. In this case, because the load is not providing the expected 50 ohm end termination, a nominal 12dB pad must be used to achieve an actual ~6dB attenuation.)

1



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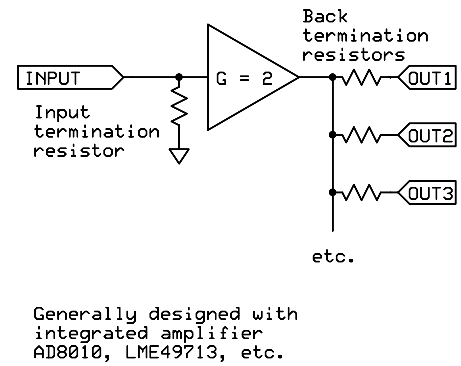

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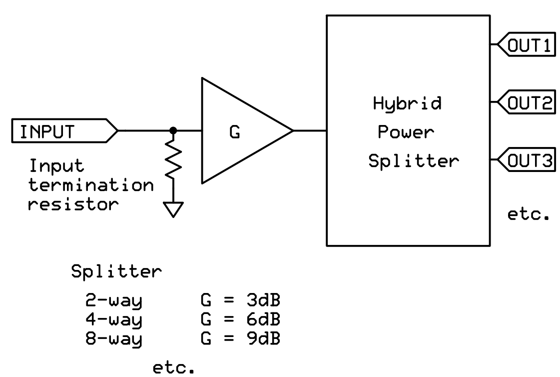

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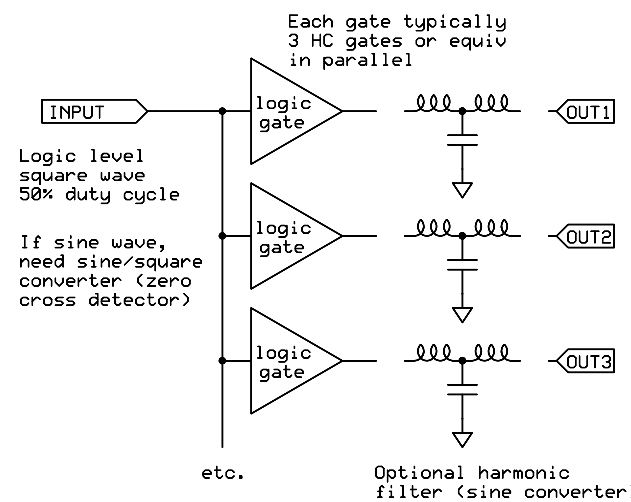
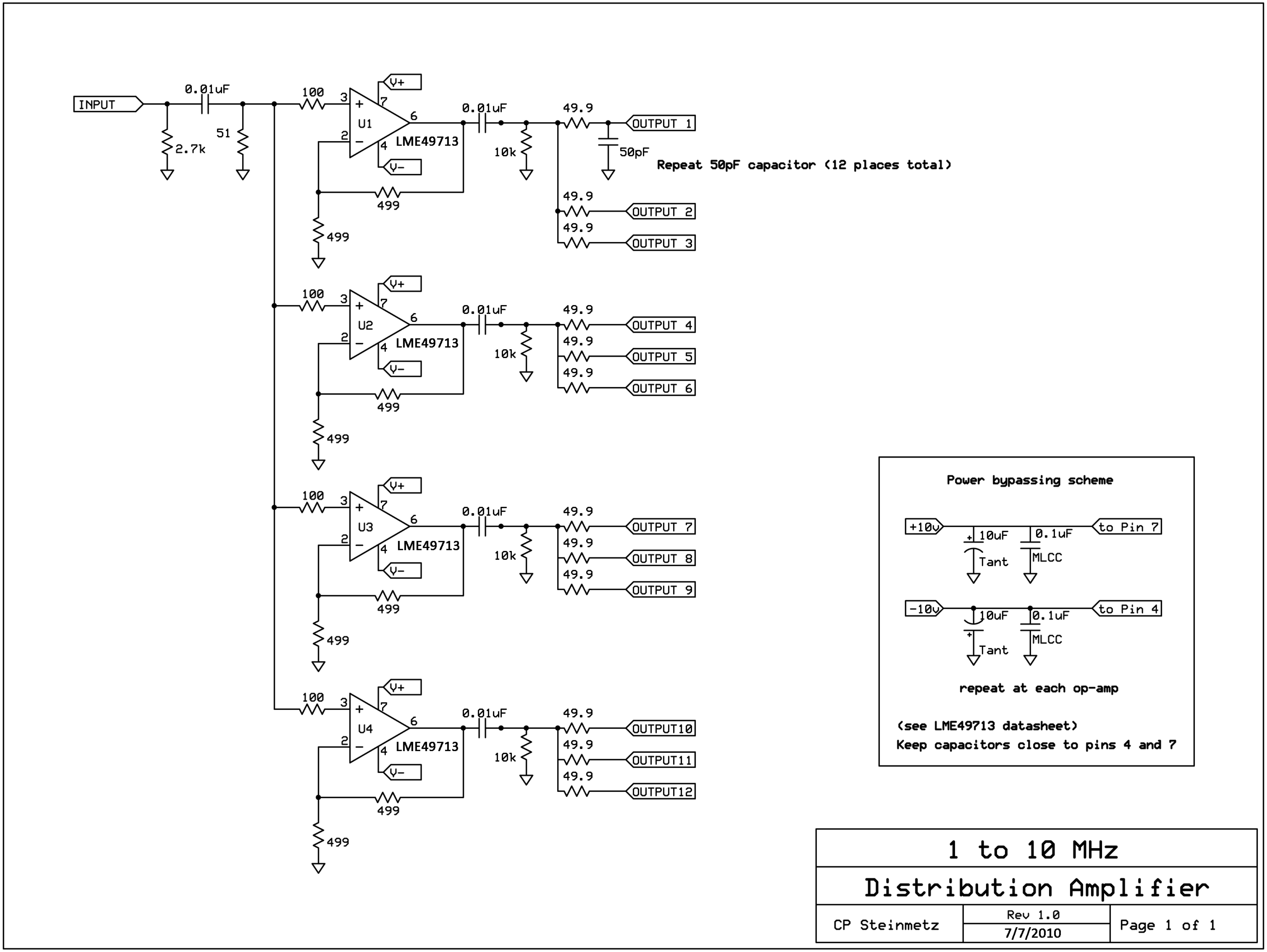
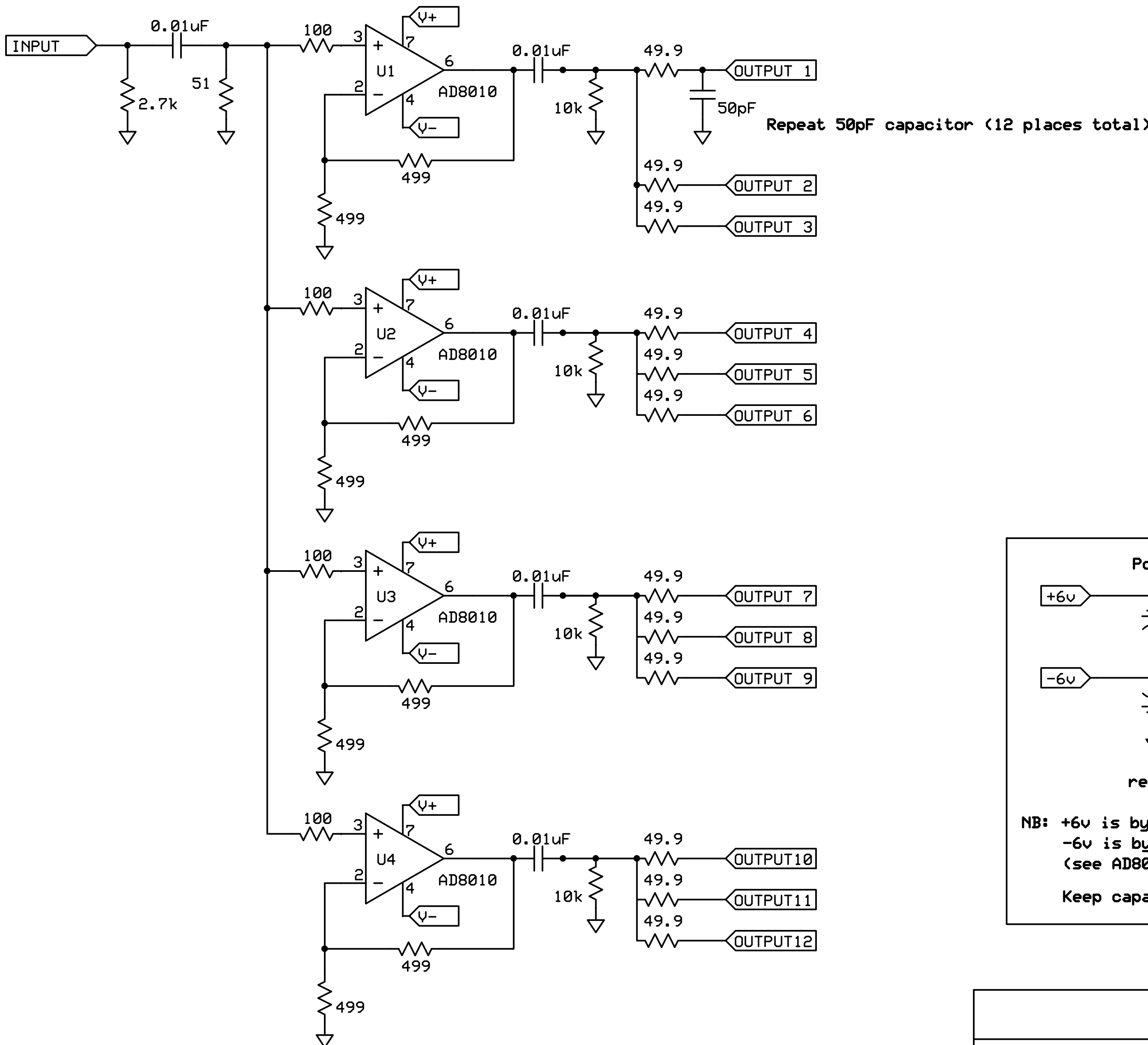
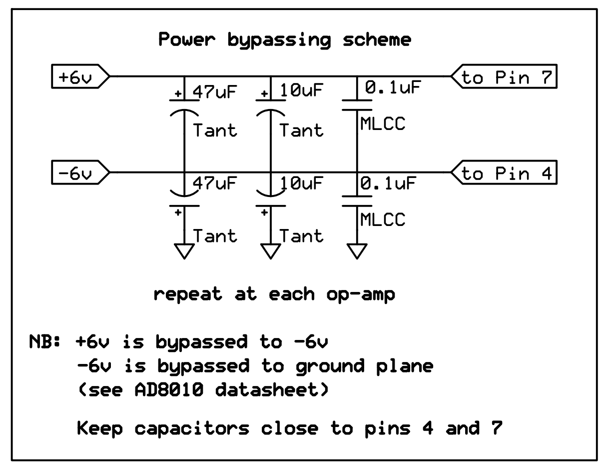


Distribution Amplifiers		
various architectures		
CP Steinmetz	Rev 1.0 9/2/2015	Page 1 of 1



INPUT
0.01uF
2.7k
51
100
U1
U2
U3
U4
LME49713
V+
V-
499
0.01uF
10k
49.9
OUTPUT 1
OUTPUT 2
OUTPUT 3
OUTPUT 4
OUTPUT 5
OUTPUT 6
OUTPUT 7
OUTPUT 8
OUTPUT 9
OUTPUT10
OUTPUT11
OUTPUT12
50pF
Repeat 50pF capacitor (12 places total)
Power bypassing scheme
+10v
10uF
Tant
0.1uF
MLCC
to Pin 7
-10v
to Pin 4
repeat at each op-amp
(see LME49713 datasheet)
Keep capacitors close to pins 4 and 7
1 to 10 MHz
Distribution Amplifier
CP Steinmetz
Rev 1.0
7/7/2010
Page 1 of 1





1 to 10 MHz

Distribution Amplifier

CP Steinmetz	Rev 1.0 4/13/2007	Page 1 of 1