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One of the most common tasks is unbalancing and reducing a broadcast signal so it may be used with domestic equipment. There are as many solutions to this problem as there are people, this is but another approach.....

Important Notes - Read them!

1. **The approach detailed here will NOT work reliably if the Broadcast Equipment uses a Transformer on its output. Some Line Driver IC's are available that simulate the behaviour of a Transformer, these also fall into this category.** Having said that, some clown will no doubt proceed to connect things together and contact us claiming the opposite. The important point is that you need to know the wiring and type of Transformer if you want a reliable and predictable connection. **Try the approach here, if it works great, if it fails you probably have one of the cases above, more info is needed.**
2. It is assumed that the output impedance of the source is "lowish" ($< 100 \Omega$) and the input impedance of the domestic equipment is "highish" ($> 20,000 \Omega$). These are not terribly difficult constraints to satisfy.
3. The whys of using balanced lines are well outside the scope of this paper, although there is a little bit of background material in "Method 4" that explains the signals.
4. The *SolutionBase®* Note "dB What" covers decibels. If you find it necessary to use Method 4, it may be helpful to peruse this other *SolutionBase®* Note before continuing.

What are we building?

If you connect the Output of Broadcast Equipment directly to the Input of Domestic Equipment it sounds distorted, there is also the difficulty that there are 3 wires on the Broadcast Equipment Output and only 2 wires on the Domestic Equipment Input, so which wires do you use?

This *SolutionBase®* Note details how to construct a simple device to solve the problem!

In "Technical terms" it is an "Attenuator" (Figure 1), roughly translating this into "human": a couple of resistors that reduce the signal so it works!

On the left of Figure 1 is a Broadcast Device (eg. Betacam, Audio Mixer,....) and on the right is a Domestic Item (eg. VHS, Audio Amp,....). In the middle is the collection of resistors (Attenuator) which reduces the signal.

We are using "standard connectors", XLR for Broadcast and RCA for Domestic. This covers most cases, the greatest variation will be on the Domestic Equipment, where "Tip and Sleeve" connectors are also common. It is "fairly safe" to assume following when converting between them:

<u>Signal</u>	<u>RCA</u>	<u>Tip and Sleeve</u>
Audio	Centre Pin	Tip
Earth	Outer	Sleeve

Anything other than these should be carefully checked. This information is usually in the "Operating Manual" or similar. If this fails a CRO or meter will solve the problem, but this will require someone with a bit more knowledge.

The problem most people face is working out the values of R1 and R2 (Figure 1), all that work has been done for you! We have supplied a number of "Methods", one of which should solve your problem.

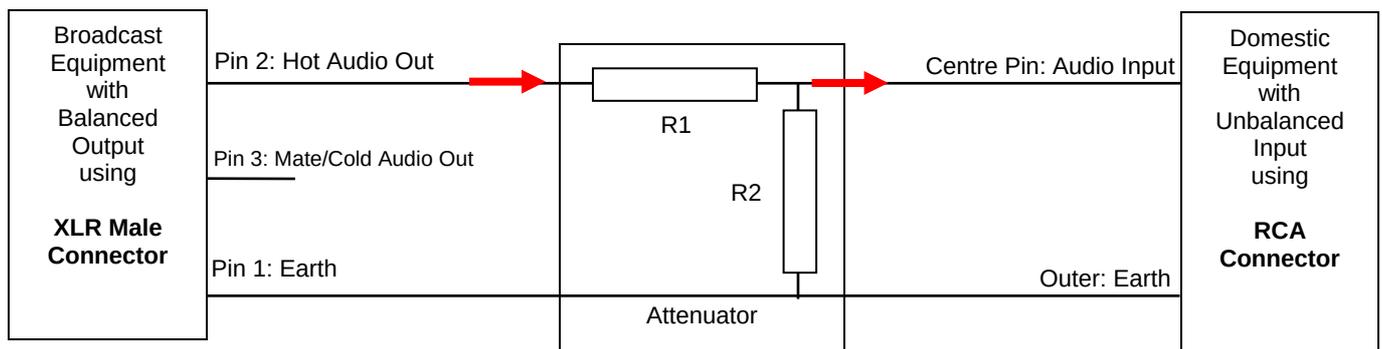


Figure 1.

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How to use this SolutionBase® Note.

4 Methods to solve the problem are provided, simply select one:

Method	Description
1	Accept our assumptions and look up the resistor values directly from Tables. This is likely to solve most requirements.
2	More flexible, we provide the resistor ratios, you to pick R2 and use a formula to obtain R1.
3	Neither of the above work because the Output or Input is specified using Voltages and not dB. Method 3 is a trick to get around this!
4	Total DIY! We provide all the formulas for you to do it from scratch!

As always, some background material is also provided.

Method 1.

Method 1 assumes that: $R2 = 1k\Omega$ (or 1000 ohms).

Procedure:

1. Determine the Output level of the Broadcast Equipment, typically this will be +4dBm (this is fairly safe to assume).
2. Determine how the Input Level of the Domestic Equipment is specified.
3. If the Domestic equipment has its input specified in dBu, we use Table 2, however, if the Domestic equipment has its input specified in dBV then we use Table 3.
4. Should the Domestic Equipment use another method (volts for example) you will need to use one of the other Methods.
5. With all the above information, turn to the appropriate Table.
6. Locate the **Broadcast Equipment Output Level (dBm)** in the **left most column of the Table**.
7. Locate the **Domestic Equipment Input Level (dB?)** across the **top of the Table**.
8. The **Resistor value (R1)** is contained **in the Table** where the **column and the row intersect**.
9. As not every Resistor value in the Table is available, you may have to use one that is "close". If confronted by this situation, select a resistor with higher value, rather than a lower valued one, this is the "safe option".

Example:

Betacam Output Level = +4dBm, VHS Input Level = -10dBu.

As the VHS uses dBu, we use Table 2.

We locate 4 in the dBm column on the left side of Table 2.

We locate -10 in the dBu row at the top Table 2.

R1 is the value where the column and row intersect = 1505 Ω .

Thus we use $R1 = 1505 \Omega$ and $R2 = 1000 \Omega$

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Method 2.

Method 2 allows you to pick the value for R2.

Procedure:

1. Determine the Output level of the Broadcast Equipment, typically this will be +4dBm (this is fairly safe to assume).
2. Determine how the Input Level of the Domestic Equipment is specified.
3. If the Domestic equipment has its input specified in dBu, we use Table 4, however, if the Domestic equipment has its input specified in dBV then we use Table 5.
4. Should the Domestic Equipment use another method (volts for example) you will need to use one of the other Methods.
5. With all the above information, turn to the appropriate Table.
6. Locate the **Broadcast Equipment Output Level (dBm)** in the **left most column of the Table**.
7. Locate the **Domestic Equipment Input Level (dB?)** across the **top of the Table**.
8. The **Multiplier** value for **R1** is contained in the **Table** where the **column and the row intersect**.
9. Select the value of R2 to suit your requirements.
10. Obtain R1 by multiplying R2 by the value from the Table.
11. As not every Resistor value in the Table is available, you may have to use one that is "close". If confronted by this situation, select a resistor with higher value, rather than a lower valued one, this is the "safe option".

Example:

For consistency, we will use the values as Method 1.
Betacam Output Level = +4dBm, VHS Input Level = -10dBu.
As the VHS uses dBu, we use Table 4.
We locate 4 in the dBm column on the left side of Table 4.
We locate -10 in the dBu row at the top Table 4.
The R1 multiplier is the value where the column and row intersect = 1.505.
For consistency we select R2 = 1000Ω
Finally we use R1 = 1.505 x R2 = 1.505 x 1000 = 1505Ω
So R1 = 1505Ω and R2 = 1000Ω which match the values from Method 1.

Method 3.

Method 3 gets around the problem of Voltages being used and not dBm, dBu or dBV.

In reality, all we are going to do is convert the Voltage into a dB value and then use Method 1 or Method 2.

Procedure:

1. If the Broadcast Equipment uses Voltage.
 - Using Table 1, Locate the Voltage in Column 3 (Voltage across Load).
 - Now locate the corresponding dBm value in Column 1 (dBm).
 - If the Voltage is not exactly specified in Column 3, use the next highest value, this is safest approach.
2. If the Domestic Equipment uses Voltage.
 - Using Table 1, Locate the Voltage in Column 6 (dBu as Voltage).
 - Now locate the corresponding dBu value in Column 5 (dBu).
 - If the Voltage is not exactly specified in Column 6, use the next lowest value, this is safest approach.
3. Now use Method 1 or 2 to find R1 and R2.

Example:

Betacam Output Level = 1.1 Volts, VHS Input Level = 0.25 Volts.
From Table 1
The best match in Column 3 is 1.22 Volts, from Column 1 we obtain +4 dBm.
The best match in Column 6 is 0.24 Volts, from Column 5 we obtain -10 dBu.
Now select either Method 1 or 2 to determine R1 and R2.

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Method 4.

This is very much for the person that knows what they are doing, we have collected all the bits you need.

- Firstly a bit of background on Balanced Lines.
- All the necessary conversion equations.
- The maths behind the basic Attenuator we use.

The *SolutionBase*® Note "dB What" covers decibels, it may be helpful to peruse it before continuing.

Balanced Lines.

A balanced line has a minimum of 2 wires, one for the "Hot" or +ve phase and the other "Cold", "Mate" or the -ve phase.

The diagram below illustrates the idea using sine waves.

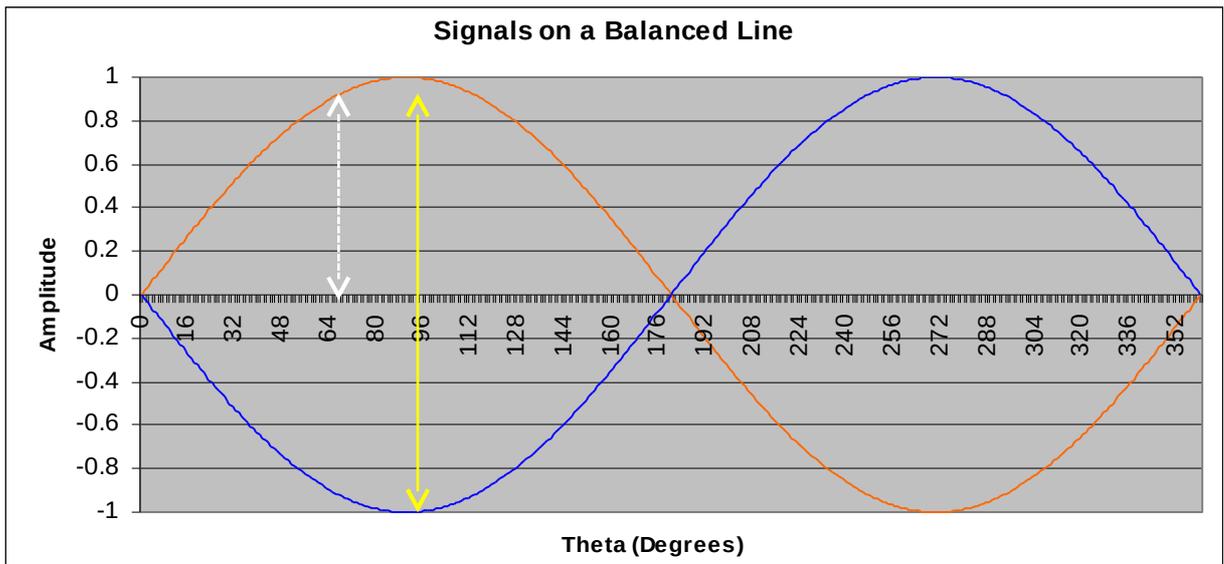
We will call the red curve "Hot" and the blue curve "Mate". Looking very closely at the curves reveals they are simply the "inverse" of the other. So using the red curve as a reference, it is at its maximum positive value of 1 when the blue is at its maximum negative value of -1. The curves follow this simple relationship for their entire length.

Plunging briefly into maths.

Red Curve = Sin (Theta)

Blue Curve = - Sin (Theta)

It can't get much more obvious how simply these curves are related!



The next nasty to sort out is measuring voltages on a balanced line. For an unbalanced line there is only a "hot" and Earth and you measure voltage between these (illustrated by the white arrow in the above diagrams). Extending this to a balanced line is simple, you measure between the "hot" and the "mate"; the yellow line illustrates this in the above.

Common sense tells us that the voltage between the "hot" and "mate" is twice that between the "hot" and Earth.

Back to some maths again.

Red Curve = Sin (Theta)

Blue Curve = - Sin (Theta)

Using the Red curve as the reference,

Voltage between them	=	Red Voltage - Blue Voltage
	=	Sin (Theta) - [- Sin (Theta)]
As we expected	=	2 Sin (Theta)

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Voltage between "Hot" and "Earth" of a balanced a 600Ω Line, using +4 dBm as the reference.

dBm is a Power ratio, so there are a number of steps involved.

$$\begin{aligned} \text{Power in the Load} &= 0.001 \times 10^{\text{dBm}/10} && \text{in this case dBm} = +4, \text{ so this becomes} \\ &= 0.001 \times 10^{4/10} \\ &= 2.512 \text{ mW} \end{aligned}$$

$$\begin{aligned} \text{The voltage across the Load: } V &= \sqrt{PR} && (\text{where } P \text{ is } 2.512 \times 10^{-3} \text{ and } R = 600) \\ &= 1.228 \text{ V rms} \end{aligned}$$

As the Load is connected across a balanced line and we connect between "Hot" and Earth, the Voltage is:

$$\begin{aligned} &= 1.228 / 2 \\ &= 0.614 \text{ Volts} \end{aligned}$$

The above calculation can be repeated for any dBm value of interest, Table 1 contains the values from -30 dBm to + 30 dBm.

Converting from dBu to Voltage.

$$\begin{aligned} \text{From the } \textit{SolutionBase}^{\text{®}} \text{ paper "dB What we have:} & V &= & 0.775 \times 10^{(\text{dBu} / 20)} \\ \text{Example using -10 dBu.} & V &= & 0.775 \times 10^{(-10 / 20)} \\ & &= & 0.245 \text{ Volts rms} \end{aligned}$$

The above calculation can be repeated for any dBu value of interest, Table 1 contains the values from -30 dBu to + 30 dBu.

Converting from dBV to Voltage.

$$\begin{aligned} \text{From the } \textit{SolutionBase}^{\text{®}} \text{ paper "dB What we have:} & V &= & 10^{(\text{dBV} / 20)} \\ \text{Example using -10 dBV.} & V &= & 10^{(-10 / 20)} \\ & &= & 0.316 \text{ Volts rms} \end{aligned}$$

The above calculation can be repeated for any dBV value of interest, Table 1 contains the values from -30 dBV to + 30 dBV.

Calculating the Voltage Ratio and Resister Values.

Using the basic Voltage Divider (shown below) we obtain the equation:

$$\begin{aligned} \text{Output Voltage:} & V_{\text{OUT}} &= & V_{\text{IN}} \times R_2 / (R_1 + R_2) \\ \text{The Voltage Ratio:} & V_R &= & V_{\text{OUT}} / V_{\text{IN}}. \end{aligned}$$

After a burst of algebra this becomes:

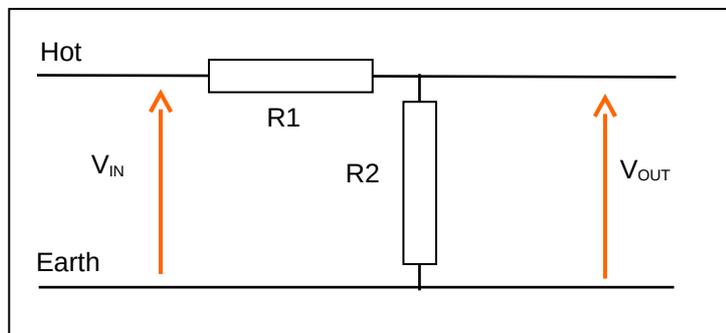
If given V_R (V_{OUT} , V_{IN}) and R_2 , then one of the following may be used to obtain R_1

$$\begin{aligned} R_1 &= R_2 (1 - V_R) / V_R \\ R_1 &= R_2 (1 / V_R) - 1 \\ R_1 &= R_2 ((V_{\text{OUT}}/V_{\text{IN}}) - 1) \\ R_1 &= ((R_2 \times V_{\text{IN}}) / V_{\text{OUT}}) - R_2 \end{aligned}$$

or if given V_R (V_{OUT} , V_{IN}) and R_1 , then one of the following may be used to obtain R_2

$$\begin{aligned} R_2 &= R_1 V_R / (1 - V_R) \\ R_2 &= R_1 V_{\text{OUT}} / (V_{\text{IN}} - V_{\text{OUT}}) \end{aligned}$$

Now simply pick either R_1 or R_2 to suit the situation and obtain the other value using one of the above equations.



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Table 1 - dBm to Voltage, dBu to Voltage, dBV to Voltage

dBm				dBu		dBV	
1	2	3	4	5	6	7	8
dBm	Power in Load	Voltage across Load	Voltage Hot to Earth	dBu	dBu as Voltage	dBV	dBV as Voltage
30	1.000000000	24.4948974	12.2474487	30	24.50765	30	31.62278
29	0.7943282347	21.8311003	10.9155502	29	21.84247	29	28.18383
28	0.6309573445	19.4569886	9.7284943	28	19.46712	28	25.11886
27	0.5011872336	17.3410594	8.6705297	27	17.35009	27	22.38721
26	0.3981071706	15.4552354	7.7276177	26	15.46328	26	19.95262
25	0.3162277660	13.7744931	6.8872465	25	13.78167	25	17.78279
24	0.2511886432	12.2765299	6.1382649	24	12.28292	24	15.84893
23	0.1995262315	10.9414688	5.4707344	23	10.94717	23	14.12538
22	0.1584893192	9.7515943	4.8757972	22	9.75667	22	12.58925
21	0.1258925412	8.6911176	4.3455588	21	8.69564	21	11.22018
20	0.1000000000	7.7459667	3.8729833	20	7.75000	20	10.00000
19	0.0794328235	6.9036001	3.4518000	19	6.90719	19	8.91251
18	0.0630957344	6.1528400	3.0764200	18	6.15604	18	7.94328
17	0.0501187234	5.4837245	2.7418622	17	5.48658	17	7.07946
16	0.0398107171	4.8873746	2.4436873	16	4.88992	16	6.30957
15	0.0316227766	4.3558772	2.1779386	15	4.35815	15	5.62341
14	0.0251188643	3.8821796	1.9410898	14	3.88420	14	5.01187
13	0.0199526231	3.4599962	1.7299981	13	3.46180	13	4.46684
12	0.0158489319	3.0837249	1.5418624	12	3.08533	12	3.98107
11	0.0125892541	2.7483727	1.3741863	11	2.74980	11	3.54813
10	0.0100000000	2.4494897	1.2247449	10	2.45077	10	3.16228
9	0.0079432823	2.1831100	1.0915550	9	2.18425	9	2.81838
8	0.0063095734	1.9456989	0.9728494	8	1.94671	8	2.51189
7	0.0050118723	1.7341059	0.8670530	7	1.73501	7	2.23872
6	0.0039810717	1.5455235	0.7727618	6	1.54633	6	1.99526
5	0.0031622777	1.3774493	0.6887247	5	1.37817	5	1.77828
4	0.0025118864	1.2276530	0.6138265	4	1.22829	4	1.58489
3	0.0019952623	1.0941469	0.5470734	3	1.09472	3	1.41254
2	0.0015848932	0.9751594	0.4875797	2	0.97567	2	1.25893
1	0.0012589254	0.8691118	0.4345559	1	0.86956	1	1.12202
0	0.0010000000	0.7745967	0.3872983	0	0.77500	0	1.00000
-1	0.0007943282	0.6903600	0.3451800	-1	0.69072	-1	0.89125
-2	0.0006309573	0.6152840	0.3076420	-2	0.61560	-2	0.79433
-3	0.0005011872	0.5483724	0.2741862	-3	0.54866	-3	0.70795
-4	0.0003981072	0.4887375	0.2443687	-4	0.48899	-4	0.63096
-5	0.0003162278	0.4355877	0.2177939	-5	0.43581	-5	0.56234
-6	0.0002511886	0.3882180	0.1941090	-6	0.38842	-6	0.50119
-7	0.0001995262	0.3459996	0.1729998	-7	0.34618	-7	0.44668
-8	0.0001584893	0.3083725	0.1541862	-8	0.30853	-8	0.39811
-9	0.0001258925	0.2748373	0.1374186	-9	0.27498	-9	0.35481
-10	0.0001000000	0.2449490	0.1224745	-10	0.24508	-10	0.31623
-11	0.0000794328	0.2183110	0.1091555	-11	0.21842	-11	0.28184
-12	0.0000630957	0.1945699	0.0972849	-12	0.19467	-12	0.25119
-13	0.0000501187	0.1734106	0.0867053	-13	0.17350	-13	0.22387
-14	0.0000398107	0.1545524	0.0772762	-14	0.15463	-14	0.19953
-15	0.0000316228	0.1377449	0.0688725	-15	0.13782	-15	0.17783
-16	0.0000251189	0.1227653	0.0613826	-16	0.12283	-16	0.15849
-17	0.0000199526	0.1094147	0.0547073	-17	0.10947	-17	0.14125
-18	0.0000158489	0.0975159	0.0487580	-18	0.09757	-18	0.12589
-19	0.0000125893	0.0869112	0.0434556	-19	0.08696	-19	0.11220
-20	0.0000100000	0.0774597	0.0387298	-20	0.07750	-20	0.10000

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Continued - Table 1 - dBm to Voltage, dBu to Voltage, dBV to Voltage

dBm				dBu		dBV	
1	2	3	4	5	6	7	8
dBm	Power in Load	Voltage across Load	Voltage Hot to Earth	dBu	dBu as Voltage	dBV	dBV as Voltage
-21	0.0000079433	0.0690360	0.0345180	-21	0.06907	-21	0.08913
-22	0.0000063096	0.0615284	0.0307642	-22	0.06156	-22	0.07943
-23	0.0000050119	0.0548372	0.0274186	-23	0.05487	-23	0.07079
-24	0.0000039811	0.0488737	0.0244369	-24	0.04890	-24	0.06310
-25	0.0000031623	0.0435588	0.0217794	-25	0.04358	-25	0.05623
-26	0.0000025119	0.0388218	0.0194109	-26	0.03884	-26	0.05012
-27	0.0000019953	0.0346000	0.0173000	-27	0.03462	-27	0.04467
-28	0.0000015849	0.0308372	0.0154186	-28	0.03085	-28	0.03981
-29	0.0000012589	0.0274837	0.0137419	-29	0.02750	-29	0.03548
-30	0.0000010000	0.0244949	0.0122474	-30	0.02451	-30	0.03162

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