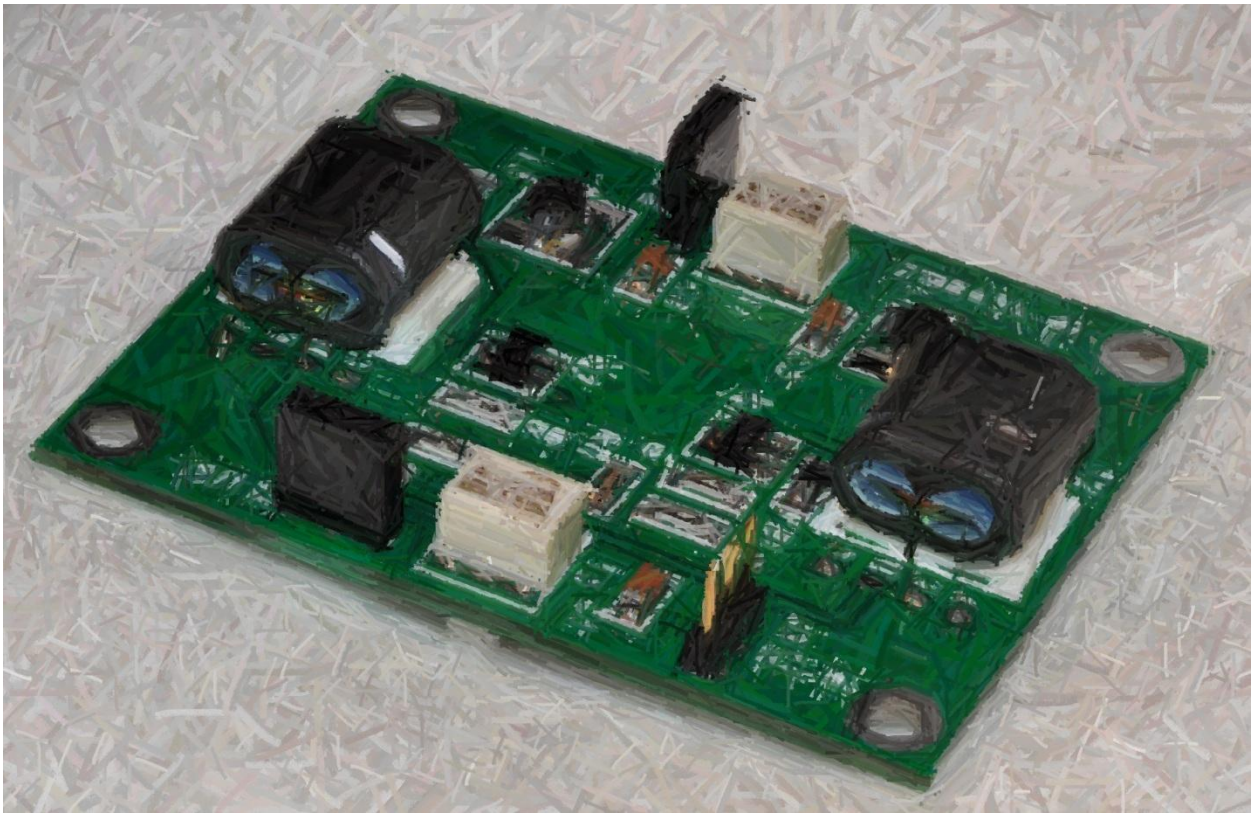
# Z10043A
# Broadband Norton Amplifier

**Assembly and Operation Manual**



*Revised 10 January 2011*

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## Table of Contents


Model Z10043A Broadband Norton Amplifier ..... 3

Trademarks and Copyright ..... 3

Warranty ..... 3

*Safety Information* ..... 4

General Information and Specifications ..... 4

Description ..... 5

Specifications ..... 6

Assembly ..... 7

Parts Provided ..... 7

Errata: ..... 9

Overview of Installing Surface Mount Parts ..... 9

Note on selection of R2 and R7: ..... 11

Component Location ..... 12

Assembly Order ..... 13

Post Construction Adjustment and Checkout ..... 20

Input and Output Connections ..... 21

Schematic and Theory of Operation and Troubleshooting ..... 23

Theory of Operation ..... 23

Schematic ..... 26

Appendix A Typical Performance Data ..... 27

Bandwidth ..... 27

Reverse Gain (Isolation) ..... 28

Noise Figure ..... 29

Input SWR ..... 30

Input Return Loss ..... 31

Appendix B – PCB Mounting Hole Dimensions ..... 32

Appendix C – Norton Amplifier Patent, US Patent No. 3,891,934 ..... 33

Appendix D Manual Backdating ..... 39

**Applicability of Manual**

This manual applies to the Z10043A printed circuit board revision 1.0 and later, identified as Z10043A-01.



# Model Z10043A Broadband Norton Amplifier

*Revised 10 January 2011*

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### Trademarks and Copyright

Material in this document copyrighted © 2010 Clifton Laboratories. All rights reserved. It is provided to allow the Z10043A purchasers to maintain their equipment and such other purposes as may not be prohibited by law.

### Warranty

This warranty is effective as of the date of first consumer purchase.

**What is covered:** During the ninety (90) days after date of purchase, Clifton Laboratories will correct any defects in the Z10043A due to defective parts or workmanship (if purchased as an assembled unit) free of charge (post-paid). You must send the unit at your expense to Clifton Laboratories, but we will pay return shipping. Clifton Laboratories' warranty does not extend to defects caused by your incorrect assembly or use of unauthorized parts or materials or construction practices.

**What is not covered:** If the Z10043A is purchased as a kit, this warranty does not cover correction of assembly errors or misalignment; repair of damage caused by misuse, negligence, or builder modifications; or any performance malfunctions involving non-Clifton Laboratories accessory equipment. *The use of acid-core solder, water-soluble flux solder, or any corrosive or conductive flux or solvent will void this warranty in its entirety.* Damage to the Z10043A or equipment connected to it caused by lightning strikes is not covered under the warranty. Whether purchased as an assembled unit or as a kit, also not covered is reimbursement for loss of use, inconvenience, customer assembly or alignment time, or cost of unauthorized service.

**Limitation of incidental or consequential damages:** This warranty does not extend to non-Clifton Laboratories equipment or components used in conjunction with our products. *Any such repair or replacement is the responsibility of the customer. Clifton Laboratories will not be liable for any special, indirect, incidental or consequential damages, including but not limited to any loss of business or profits.*

**Under no circumstances is Clifton Laboratories liable for damage to your equipment connected to the Z10043A resulting from use of the Z10043A, whether in accordance with the instructions in this Manual or otherwise.**

## *Safety Information*

The Z10043A operates with a user-supplied DC power supply of 13 to 15 Volts at 100 to 120 mA. The Z10043A, although designed as a low signal level preamplifier, is capable of RF output power approaching the 1 watt level. This output power is capable of damaging receivers or the receiver section of a transceiver or test equipment. It is the user's responsibility to ensure that the Z10043A is properly connected to whatever devices it will be used with.





The Z10043A is designed to be used only with receive-type power levels. It should not be used with transmitting equipment. The Z10043A's maximum permitted input RF power is 100 mW (+20 dBm). *Power in excess of this level may damage the Z10043A or equipment connected to it, or both. In addition, since the Z10043A has appreciable gain, output power levels sufficient to damage connected equipment may occur with input signal levels well below +20 dBm.*



*Note that in order to reduce the Z10043A's physical size, reverse polarity protection, over voltage protection and antenna input protection is not provided. If these features are important to you, other Clifton Laboratories Norton amplifiers should be considered.*

## General Information and Specifications

### Description

The term "Norton Amplifiers" refers to a class of transformer feedback amplifiers developed by Dr. David Norton and described in his US Patent No. 3,891,934, granted June 24, 1975 and now in the public domain. (A copy of Dr. Norton's patent is Appendix C to this Manual.) A Norton amplifier permits the distortion reducing benefits of negative feedback to be applied without impairing the amplifier's noise figure. Hence, Norton amplifiers are also known as "noiseless feedback" amplifiers.

The Z10043A is a broadband (25 KHz to 20 MHz) Norton-style amplifier providing 11 dB gain (other gain values are possible) with very high 3rd order and 2nd order intermodulation intercepts, IP3 and IP2, respectively, with a noise figure of approximately 2 dB. (With certain component changes, the noise figure will approach 1.4 dB. See later discussion in this Manual.)

The Z10043A is derived from the Norton Amplifier developed by Dr. Dallas Lankford and described in his publication *Common Base Transformer Feedback Norton Amplifiers*, dated 8 June 1994, revised 21 May 2007, available at http://www.kongsfjord.no/dl/Amplifiers/Common%20Base%20Transformer%20Feedback%20Norton%20Amplifiers.pdf.

The Z10043A modifies Dr. Lankford's design in several respects:

- Shunt fed to reduce effect of DC saturation of T2 and T4
- Binocular core feedback transformers instead of toroids.

The Z10043A is available as a kit, including a double sided, silk screened solder masked printed circuit boards and all electronic parts or as an assembled and tested printed circuit board.

Typical kit construction time is two to three hours, depending on your work practices. The kit is suitable for relatively inexperienced builders, although Clifton Laboratories does not recommend it to purchasers who have never built an electronic kit before.

## Specifications

| Parameter | Value |
|---|---|
| **PCB Dimensions** | 2.475” x 1.975” x 0.75”. (63mm x 50mm x 19mm). Four mounting holes for 4-40 screws provided, template in Appendix B. |
| **DC Power Required** | Maximum: 15V<br>Minimum: 13.8V [may not meet specifications below this voltage.<br>Negative to ground, typical DC current 60-100 mA depending on idle current setting. |
| **Maximum RF Power Input** | Do not exceed 100 milliwatts (+20 dBm). IP3 performance specifications are based upon 0 dBm output (approximately -11 dBm signal input); performance not warranted at greater input levels. |
| **Test Conditions** | Performance data is for a 1:11:4 turns ratio design, 13.8 VDC. Figures stated as “typical” are not warranted. |
| **3 dB Bandwidth** | 100 KHz – 30 MHz. (Typical 3 dB bandwidth 45 KHz – 55 MHz) |
| **2nd and 3rd Order Intermodulation Intercept** | Measured with 3 and 4 MHz input tones, adjusted for 0 dBm output from the Z10043A. Protocol as discussed later in this manual. Intercepts are output referenced.<br>OIP2: +80 dBm (typically > +90 dBm)<br>OIP3: +45 dBm (typically +49 to +50 dBm) |
| **Gain** | 11 dB nominal at 1 MHz. |
| **1 dB Gain Compression** | +19 dBm input. |
| **Noise Figure** | 2.5 dB maximum 10-30 MHz. Typically 2 dB or less at 10 MHz. When configured for best noise figure, typically 1.4 dB |
| **Input VSWR** | When terminated with 50 ohm load, input VSWR is less than 2:1 over the range 300 KHz – 30 MHz, and is typically below 1.5:1 over this range. |

## Assembly

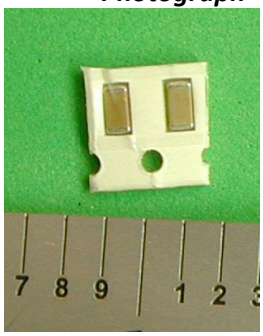
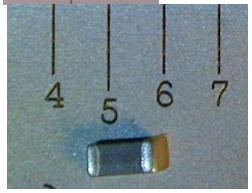
### Parts Provided

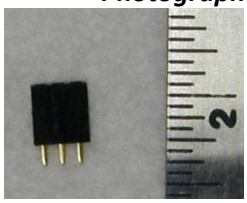
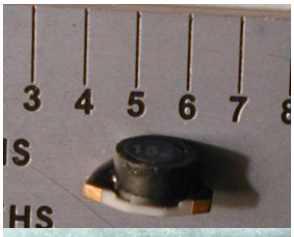
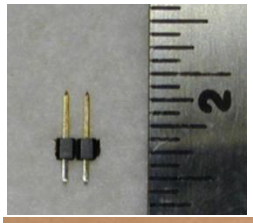
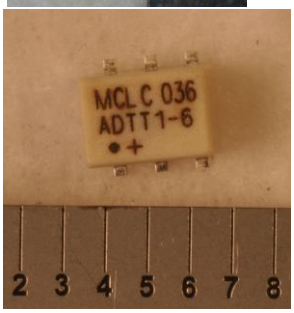
Before starting your build, please take a moment and inventory the parts provided against the list below. The ruler is marked in decimal (tenths) inches. One inch is 25.4mm and 0.1 inch is 2.54mm. (Some older photos use a ruler marked in fractions of an inch, such as 1/16th.)

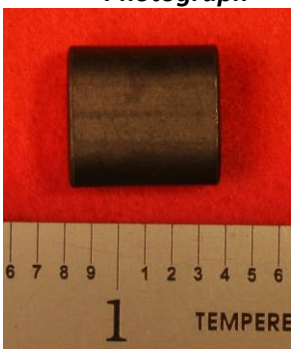
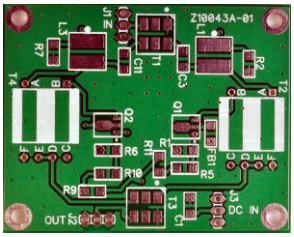
⚠ Many parts in this kit are not marked and can easily be confused. Parts are provided in individually labeled paper envelopes. Please keep parts in the associated envelope when not being installed.

**A note on how component values are identified in this manual**

This document follows the international practice of using the value multiplier to indicate the decimal point. Thus, a 1.0µF capacitor is identified as 1µ0 and a 10,000 ohm resistor is identified as 10K0.

| *Photograph* | *Qty* | *ID* | *Description and Comments* | *Component Marking* |
|---|---|---|---|---|
|  | 12 | C1, C2, C3, C4, C6, C7, C10, C11, C14, C15, C16, C18 | 1u0 X7R 25V, 1206 size surface mount ceramic capacitors. | None |
| *Same as above* | 4 | C20, C21 | 10pF, C0G 50V, 1206 size surface mount ceramic capacitors | None |
| *Same as above* | 2 | C5, C8 | 1000pF, C0G 50V, 1206 size surface mount ceramic capacitors | None |
|  | 1 | C19 | 10uF/25V 105°C aluminum electrolytic capacitor. | 10 EHA |
|  | 2 | FB1,FB3 | Surface mount ferrite bead | None |

| *Photograph* | *Qty* | *ID* | *Description and Comments* | *Component Marking* |
|---|---|---|---|---|
|  | 3 | J1, J2 and input for J3. | J1 & J2 installed as sockets. J3 installed as pins, to mate with 3-pin socket | None |
|  | 5 | L1, L2, L3, L4, L5 | 1m0 RF choke (shielded) | 102 |
|  | 2 | Q1, Q2 | NPN transistor, UHF, type BFQ18, SOT-89 package | FF |
| | ¼ watt, 1% 1206 Surface Mount Resistors | | | |
|  | 2 | R1,R6 | 560R | 5600 |
| | 2 | R2,R7 | 71R5 | 71R5 |
| | 2 | R10, R5 | 1K50 | 1501 |
| | 2 | R9,R11 | 10R0 | 10R0 |
|  | 9 | J3 | Total of 9 pins supplied. Pins are 0.1 inch spaced, 0.025 inch square gold flashed. 3 pins to mate with J1; 3 pins to mate with J2 and 3 pins for J3. | None |
|  | 2 | T1 & T3 | Mini-Circuits ADTT-1-6 transformer, 1:1 ratio | ADTT-1-6 |

| *Photograph* | *Qty* | *ID* | *Description and Comments* | *Component Marking* |
|---|---|---|---|---|
|  | 2 | T2, T4 | Binocular core, BN73-202 type. Builder to wind T2 & T4. | None |
|  | 1 | PCB | Printed circuit board. Identified as Z10043A | Z10043A and revision number |
| *None* | Two lengths #30 magnet wire. One green and one red. | None | Used to wind T2 & T4. Red wire length 6" (150mm); green wire length 40" (1 meter) | None |
|  | 3 inches (75mm) Teflon tubing | None | Inserts for T2 & T4 | None |
| *None* | 1 inches (25mm) foam tape | None | Length of ½ inch (12mm) wide, double sided foam tape | None |
| *None* | Heat shrink tubing | | Lengths of red and black heat shrink tubing | None |

**Errata:**

None known for revision 1.0

**Overview of Installing Surface Mount Parts**

1. You may wish to apply a sparing amount of liquid flux to pads before soldering. Clifton Laboratories uses MG Chemical flux, part number 835-100ML (also available as a flux pen, part number 835-P.) Both products are available from Mouser and other suppliers. To apply liquid flux, a wooden toothpick may be used or the flux can be dispensed from a needle oiler. (If using the flux pen, wipe it across pads before soldering.) MG Chemicals 835 flux leaves a distinct residue. The residue will not damage the board but if desired, it

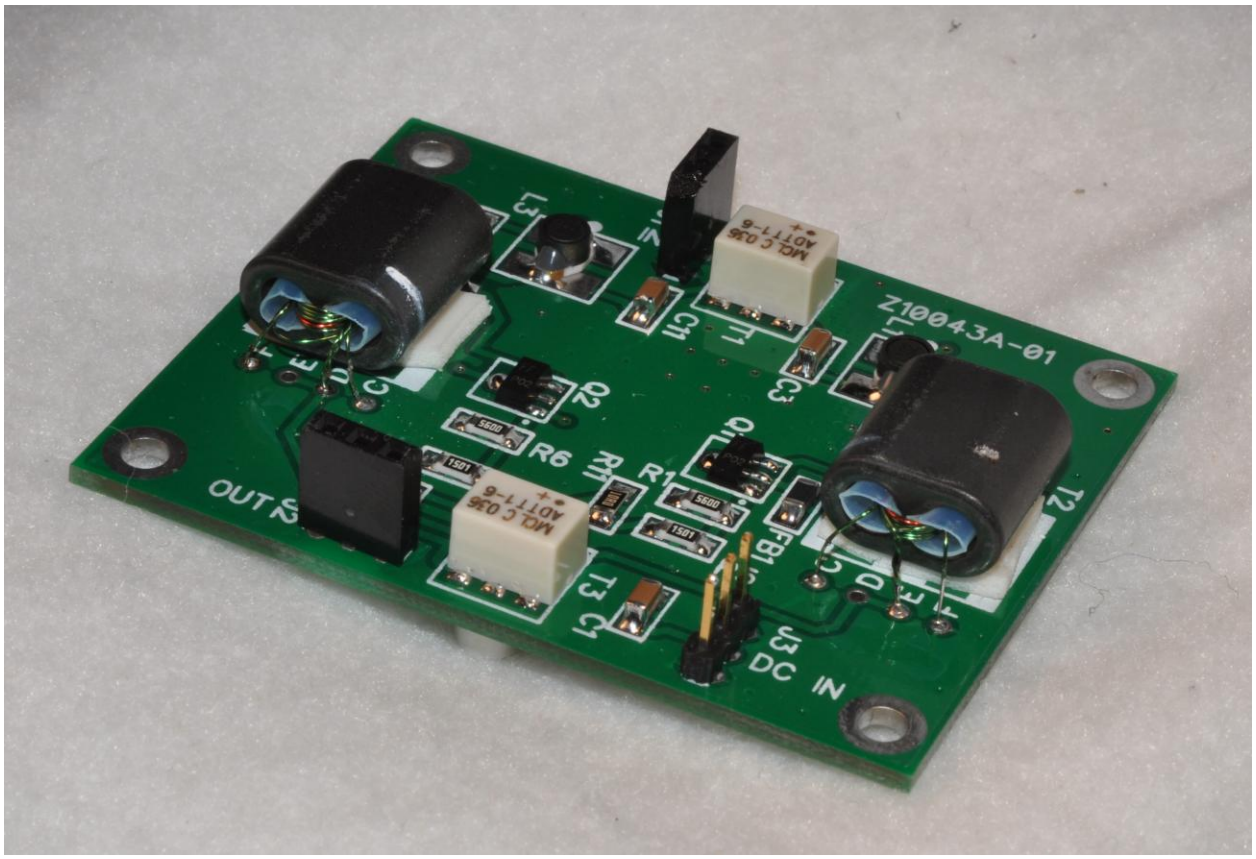





may be removed with flux remover or 91% isopropyl alcohol available locally.

2. If the component has one pad that is a ground, lightly tin the non-ground pad. If neither pad is a ground connection, tin either one of the pads.
3. Using forceps or a very light touch with long nose pliers, slide the component into place while heating the tinned pad. Check that the component is more or less centered on the pads and remove the soldering iron when centered. Too much pressure will crack these parts so use a light touch.
4. Solder the other pad. Touch up the first pad if necessary.
5. Although the Z10043A's ground pads use "thermal relief" it may still be difficult to make with a small soldering pencil, as the large foil area requires more heat capacity than a normal floating pad.

The image below shows an assembled Z10043A.




### Note on selection of R2 and R7:

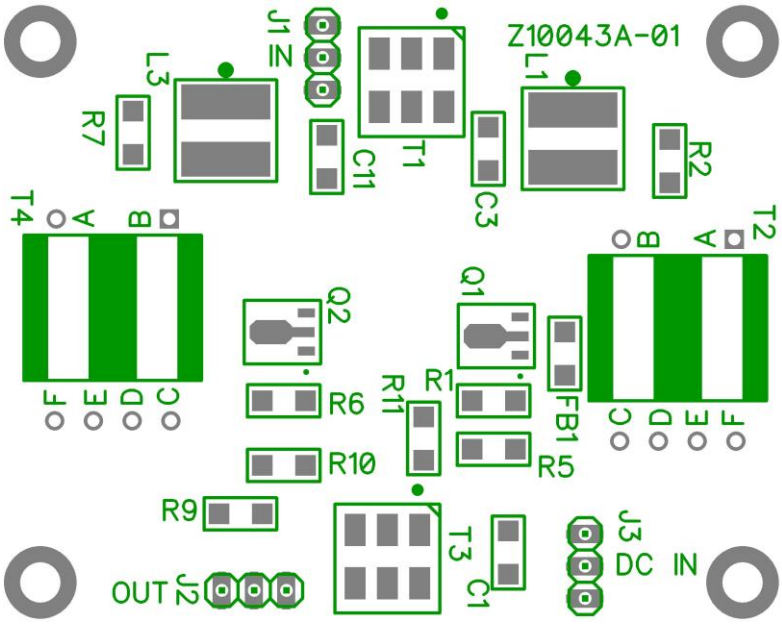
Resistors R2 and R7 determine Q1 and Q2's idle current. For operation at 13.8V DC, and for best 2nd and 3rd order intercept points, Clifton Laboratories recommends 71R5 for R2 and R7. These values are supplied with the Z10043A. The noise figure will be approximately 2 dB.

If reduced 2nd and 3rd order intercepts are acceptable, it is possible to improve the noise figure to approximately 1.4 dB by increasing R2 and R7 to 182 ohms and reducing the supply voltage to 9V.

| R2 & R7 (ohms) | Supply Voltage | Total Supply Current | Typical Noise Figure | Typical OIP2 (dBm) | Typical OIP3 (dBm) |
|---|---|---|---|---|---|
| 71.5 | 13.8 | 75mA | 2.0 dB | > +90 | +48 to +50 |
| 182 | 9 | 25mA | 1.4 dB | > +80 | +33 |

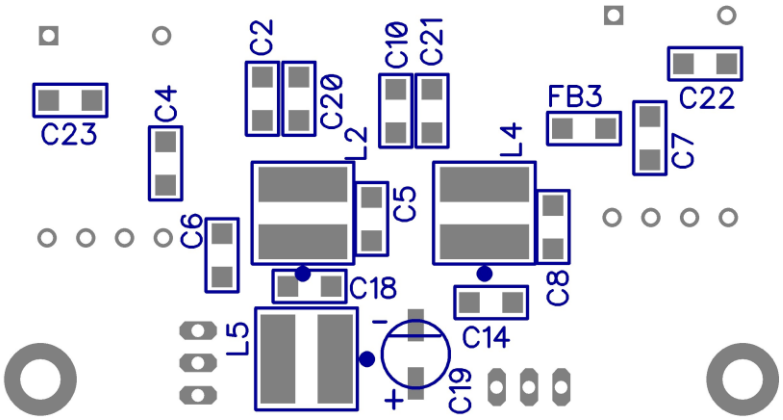
## Component Location

*TopV iew*




*Bottom View*



### Assembly Order

The Z10043A is a relatively simple kit. The most complex part is winding the transformers, and even this is not difficult.

The assembly order starts with the bottom surface.

- ❑ Install 1u0 capacitors at 6 places:
  C2
  C4
  C10
  C15
  C16
  C6

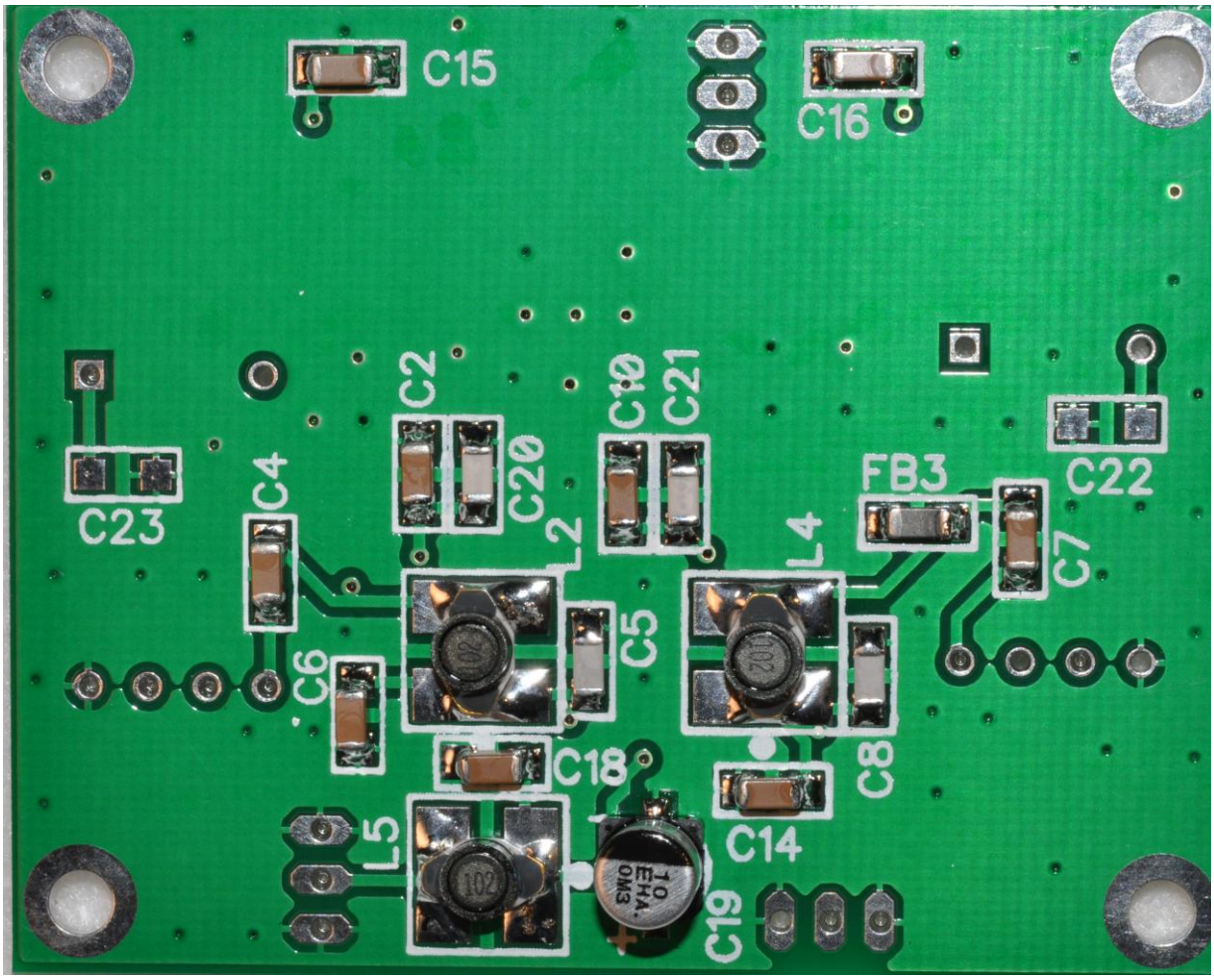
- ❑ Install 1000pF capacitors at 2 places:
  C5
  C8
- ❑ Install 10pF capacitors at 2 places:
  C20
  C21
  *Note: C22 & C23 are unused.*

- ❑ Install ferrite bead FB3

- ❑ Install 1u0 capacitor at C7
- ❑ Install 1mH inductors, marked 102 at:
  L2
  L4
- ❑ Install 1u0 capacitor at C18
- ❑ Install 1mH inductor, marked 102 at L5
- ❑ Install 1u0 capacitor at C14
- ❑ Install C19, a 10uF electrolytic capacitor marked 10. <u>This is a polarized part and must be installed with the correct orientation</u>. *Negative is indicated with black stripe on the capacitor body.*

  C19 may be difficult to properly solder as its leads are largely below the base insulator. Before soldering, tin C9's positive lead. Apply a small amount of solder to C19's PCB pad. While heating the positive pad with the soldering iron, hold C19 in place and apply a small amount of pressure with your fingers or forceps. After soldering the positive pad, verify it is properly attached; C19 should not move under light pressure. Then solder the negative terminal.

  This completes assembly of the bottom PCB surface. Note that C22 and C23 are not used. The completed board is pictured below.




Now install parts on the top surface.

- ❑ Install 1u0 capacitors at 2 places:
  C3
  C11

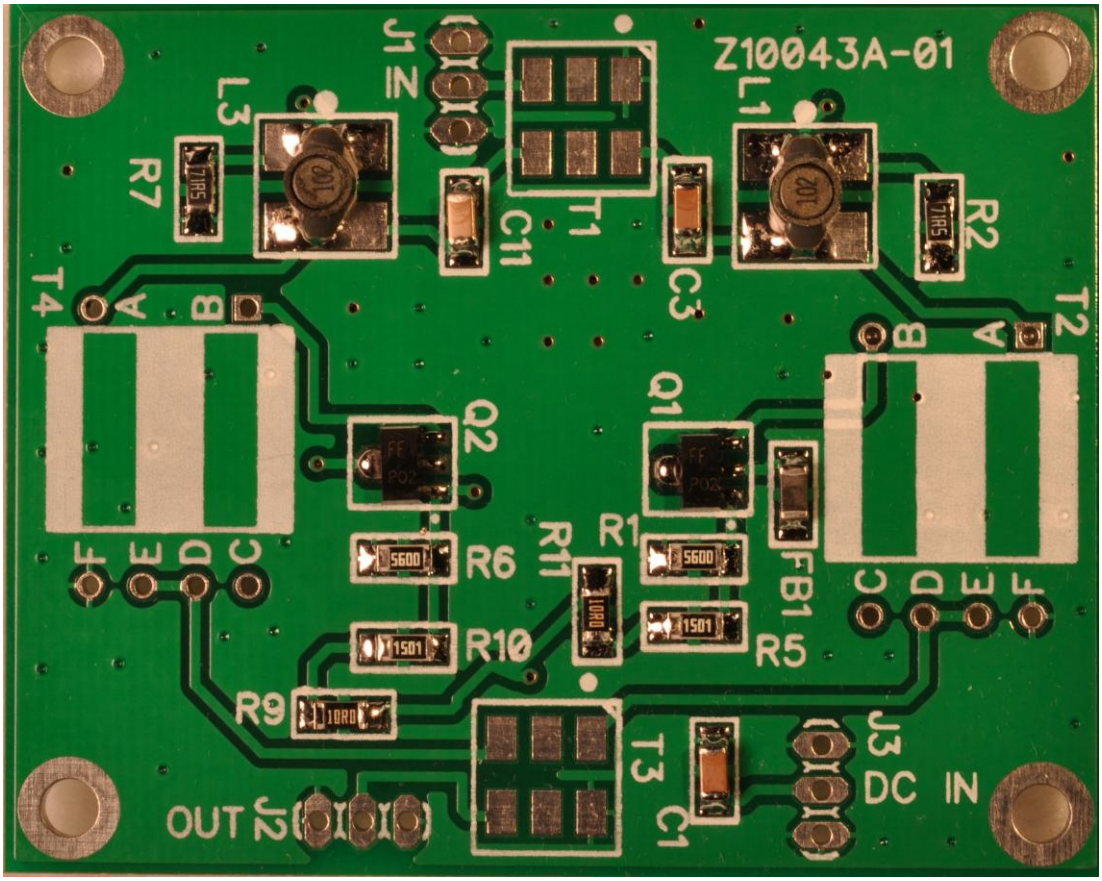
- ❑ Install R2 and R 7. For normal 13.8V operation, and for optimum intermodulation performance, these will be 71R5 parts, marked 71R5. See discussion earlier in this manual for low noise figure optimization.
- ❑ Install 1mH inductor, marked 102 at:
  L1
  L3
- ❑ Install Q1 and Q2, BFQ18 transistors, marked FF.

  To install Q1 and Q2, Apply a small bit of solder to one outside pad. Hold the transistor in place with tweezers and apply heat to the top of the pin, melting the solder on the pad beneath the pin. Solder the remaining two pins in place and reflow the tacked pin. Then solder the collector tab in place.

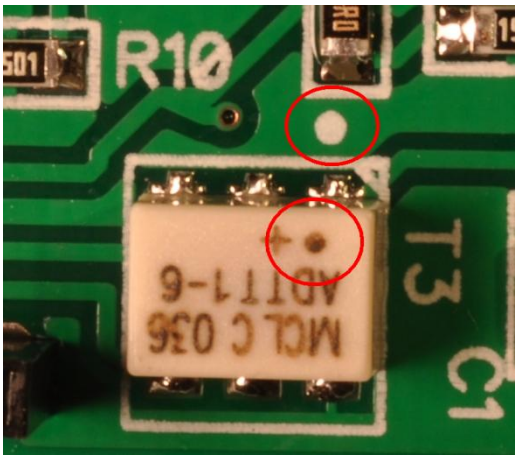
- ❑ Install 1u0 capacitor at C3

- ❑ Install 10R0 ohm resistors (marked 10R0) at:
  R9
  R11
- ❑ Install 560R resistors (marked 5600) in 2 places:
  R1 & R6
- ❑ Install 1K50 resistors (marked 1501) in 2 places:
  R5 & R10
- ❑ Install ferrite bead (unmarked) at FB1

At this point, all parts except for T1-T4 and J1-J3 should be installed on the top surface and the board should appear as pictured below.



❑ Install T1 and T3, marked ADTT-1-6.

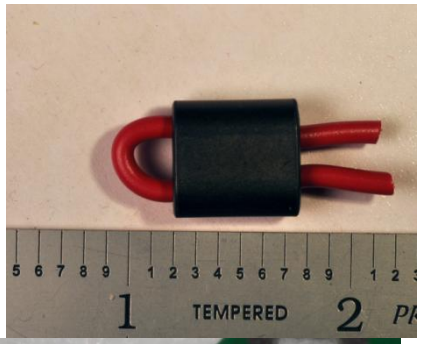



T1 and T3 have a small dot orientation mark. Install the transformers so that the dot mark is on the same side as the dot on the silk screen.

The PCB pads for T1 and T3 are a tight fit for T1 and T3 leads. Orient the transformer carefully before soldering.

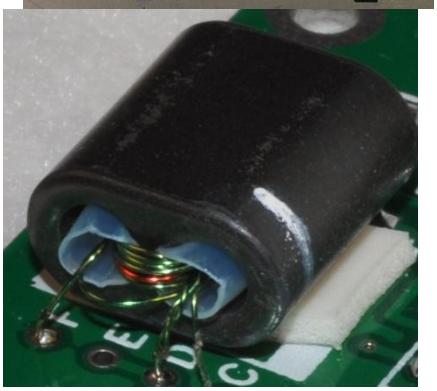
In addition, after soldering verify that the pads are soldered to the pads as it is easy to have the solder adhere only to the transformer lead and not to the underlying PCB pad.

❑ Wind transformers T2 and T4




T2 and T4 are wound on multi-aperture (binocular) cores. <u>When counting turns, remember that one turn requires the wire to pass through both holes.</u> The photo at right shows one complete turn through a binocular core. Passing the wire through one hole counts as one-half of a turn.

❑ Make a mark on one corner of each core. This mark will be used to properly orient the core for winding and installation.



Clifton Laboratories uses a white marker to provide contrast with the dark core.

<u>Notes in winding T2 and T4</u>

- T2 and T4 are ferrite cores and have sharp edges. To avoid wire damage caused by abrading the enamel insulation during winding, Teflon insert bushings are used.

The magnet wire supplied with the Z10046A is “solder strippable” which means that the insulation will dissolve in molten solder. First wind the transformer and after winding hold the transformer in place with a soft jaw vise. Cut the lead length to the recommended value and apply the soldering iron to the wire end. Add solder to form a ‘blob’ of molten solder. After a few seconds, the insulation will begin to dissolve. Work the soldering iron along the wire, adding fresh solder as necessary to maintain a blob of molten solder. Do not tin right up to the core; tin only to within 1/8th inch (3mm) of the core.

❑ Cut four bushings from the length of Teflon tubing. The bushings should slightly extend (between 1/16th and 1/32nd inch [1.5mm to 0.75mm]) from each end of the core when inserted.

When cutting the Teflon tubing, use a sharp hobby knife or a razor blade. Scissors or dull wire cutters can leave a ragged edge. After cutting, roll the tubing between your fingers to restore it to circularity.

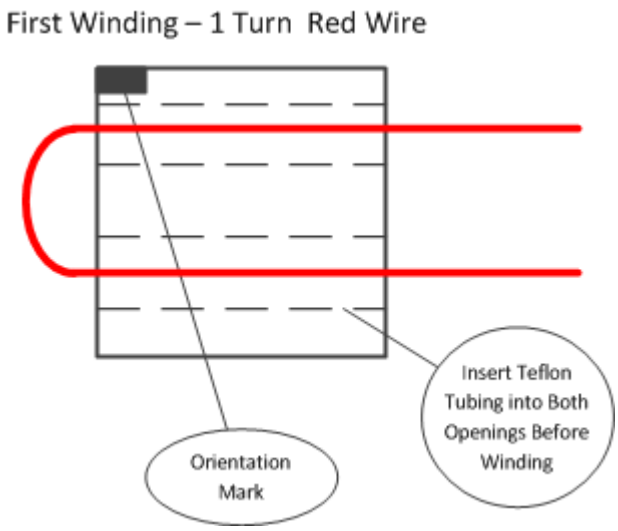
Insert the Teflon bushings into the core openings.

❑ Cut 3 inches (75mm) of red #30 magnet wire.

Wind <u>one turn</u> through the core and Teflon bushings.

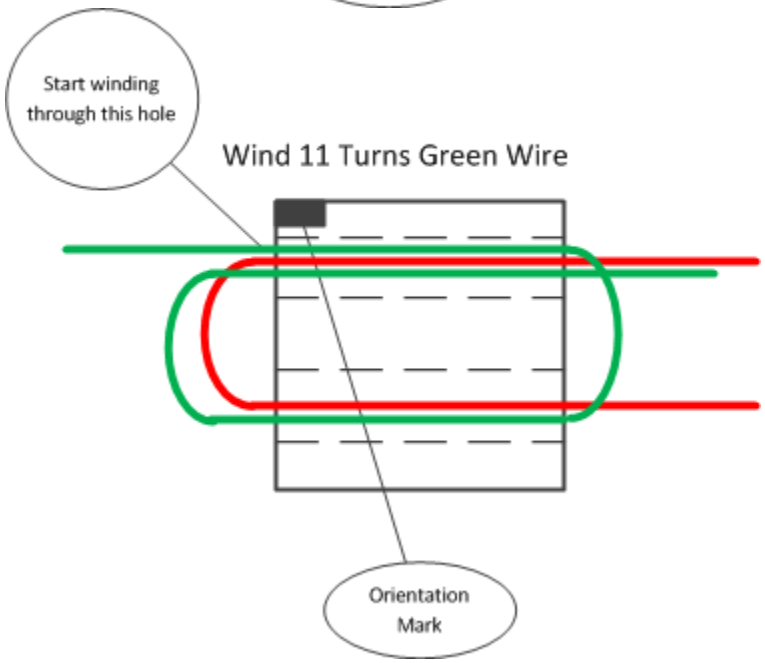
Note the orientation mark. The wire ends exit from the core on the opposite end from the orientation mark.

To retain the wire in place, lightly twist the free ends together. The loop end of the "U" should be tight against the core end.



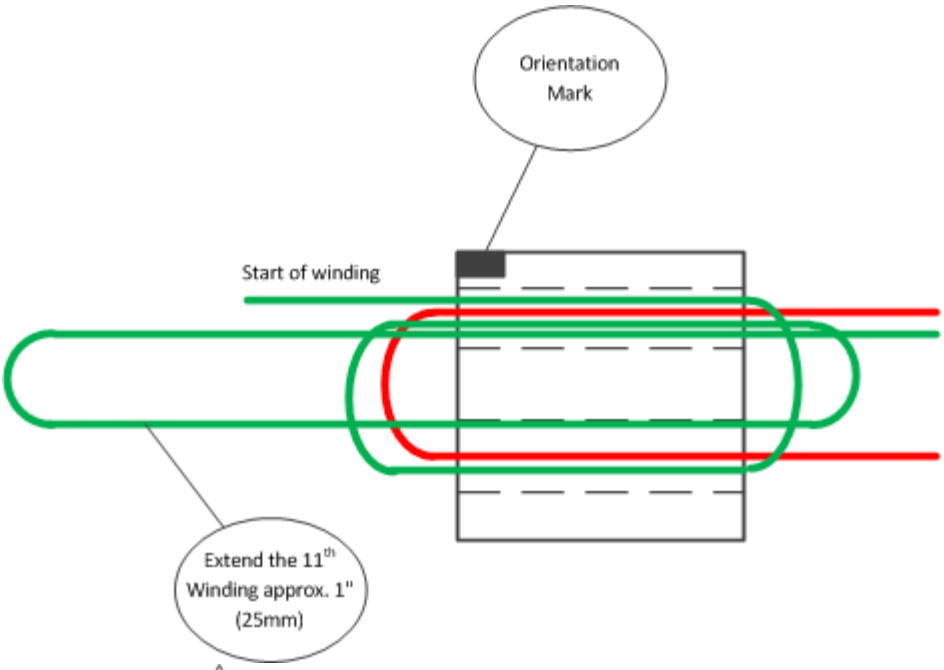

❑ Cut a length of green wire 20 inches (0.5m) long. Insert the wire into the hole nearest the orientation mark. Push the wire through the hole until approximately 1 inch (25mm) remains.

Wind 11 turns (remember – the wire must pass through both holes to count as one complete turn).



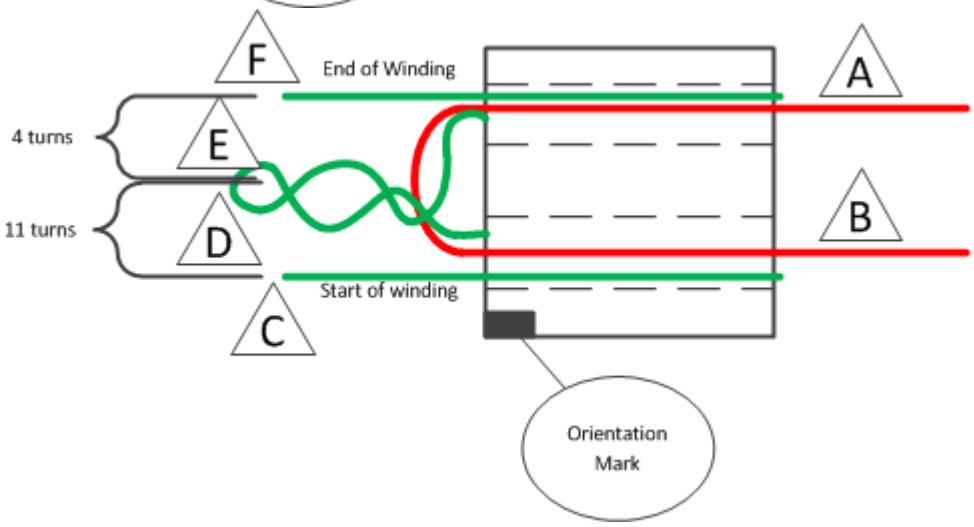
After the 11th turn, extend the winding approximately 1 inch (25mm) and wind 4 additional turns.

Twist the extended loop wires together.



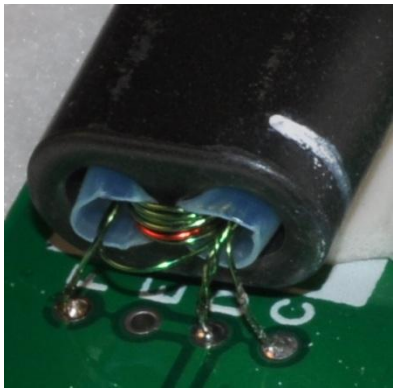

A completed transformer is illustrated at the right, along with the identification letters to match T2 & T4 PCB silk screen.

Note that the orientation mark is at the lower side in this illustration.




- ❑ Tin and remove insulation from the transformer leads. It is not necessary to separate the twisted leads D and E if they are tightly twisted as they will fit into one PCB hole.

- ❑ Cut squares of foam tape, and apply to the PCB at T2 and T4. The foam tape should not cover the solder pads.



Remove the protective covering from the foam tape and install the transformers. Installation will be easier if the leads are pre-formed to fit the holes before removing the protective paper from the foam tape.

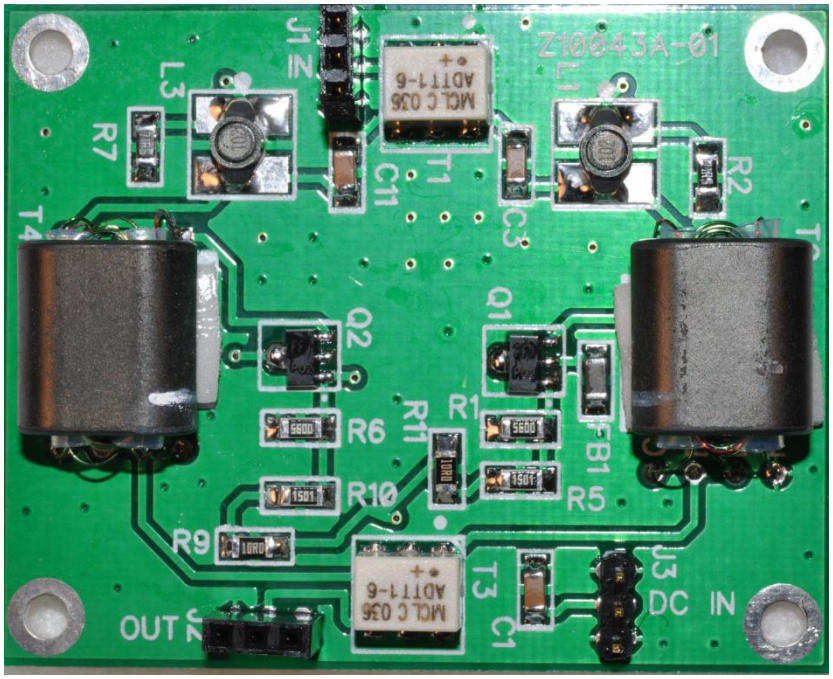
The transformers are installed so that the orientation mark is adjacent to the pad identified "C."

Note that that each solder pad hole is identified with letters

A…F.

Since leads D and E are connected together in the PCB, these two leads may remain twisted together and can be inserted in either the D or the E pad holes.

- ❑ Install three-pin header sockets (female) at J1 and J2.
- ❑ Cut or break a 3-pin section from the male header pin strip. Install at J3. . (The short side goes into the pad holes.)
  This completes assembly of the Z10043A amplifier.



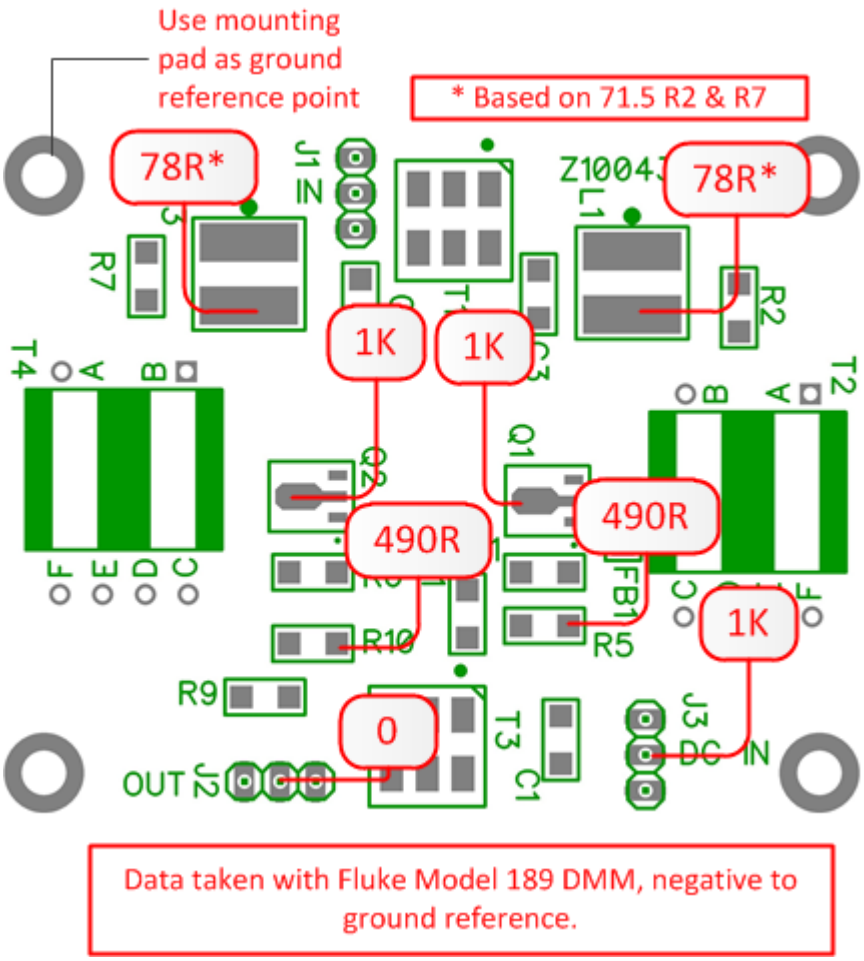
## Post Construction Adjustment and Checkout

Before powering up the Z10043A, take a moment to make resistance checks.

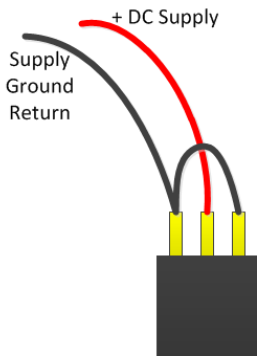
The resistance readings below are taken with a Fluke model 189 digital multimeter. Different ohmmeters may produce different resistance readings due to higher or lower open circuit test voltages than found in the Fluke 189.

In general, look for substantially identical readings in both circuit halves; the circuits around Q1 and Q2 are identical and should have matching resistance readings.

❑



❑ If you have not already done so, make up a power cable using a three-pin header socket. Positive to the center pin and negative to the two outside pins.




Insulate the connections with heat shrink tubing.

The DC power connector mates with J3.

J3 pins 1 and 3 are ground so the DC power plug may be connected to J3 in either orientation.

❑ The Z10043A will work with DC supply voltages up to 15V and down to 9V. Performance data is based upon 13.8V DC.

⚠ The high performance transistors in the Z10043A are not as resistant to over-voltage as the through-hole parts used in the Z10040B Norton Amplifier. Accordingly, do not exceed 13.8V supply unless you know exactly what you are doing.

⚠ If a laboratory power supply with current limiting is available, set it for a maximum short circuit current of 175 mA and set the voltage to 0V. Connect the supply to the Z10043A at J3 using the cable constructed above and bring up the voltage slowly whilst observing the current. With the recommend 71.5 ohm values for R2 and R7, the maximum current observed should be approximately 100 mA at 13.8V. If significant deviations from this value are observed, immediately remove power and investigate.

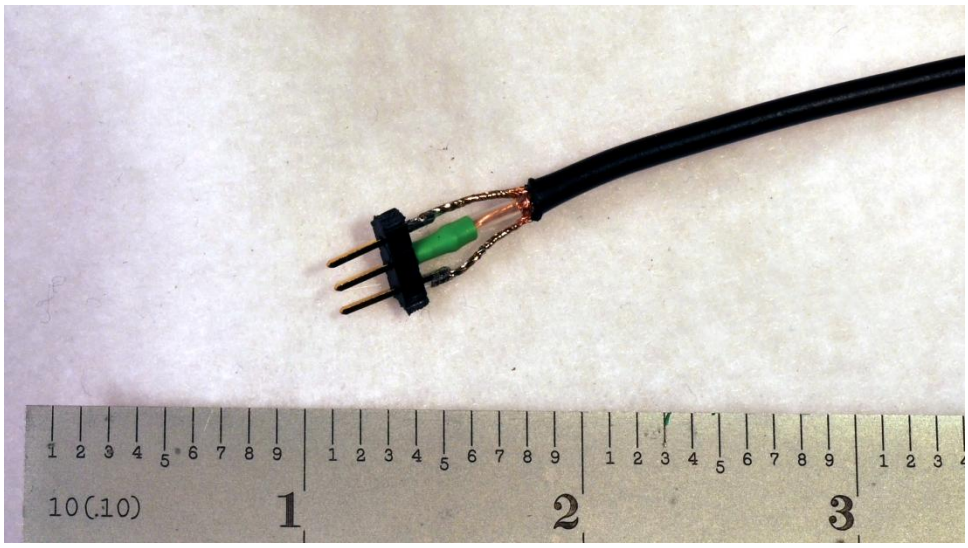
❑ Alternative 1: If you do not have the ability to measure 3rd order and 2nd order intermodulation products, adjust R3 and R8 such that Q1 and Q2 have substantially equal emitter currents of approximately 37.5 mA each, using the method above.

### Input and Output Connections

RF input and output connections are made to the Z10043A with a 3-pin headers at J1 and J2. Since the outside pins are always ground, either orientation is permitted.

#### *Note on Coaxial Cable and Header Pins*

Header pins of the type used in the Z10043A are suitable for small diameter coaxial cable, such as RG-174 (0.1 inch / 2.5mm diameter). Since the Z10042A is normally installed in an enclosure, a short jumper cable made from RG-174, or RG-178 is used between the enclosure's coaxial connectors and the Z10043A's J1 and J2.




Clifton Laboratories makes coaxial cable connections to three pin headers as illustrated in the photo below (RG-174 is illustrated).

Tin the solder ends of a 3-pin connector (the short ends).

Remove approximately 5/8th inch (15mm) of jacket from the cable. Comb the cable braid into individual wires and separate into two roughly equal groups. Twist each group together and tin the ends. Don't apply excessive heat at it is easy to melt RG-174's center conductor insulation. Remove approximately 1/8th inch of insulation from the center conductor and tin. Slip a short length of heat shrink tubing over the center conductor.

Solder the center conductor to the center pin, working quickly to avoid melting the RG-174's center insulation. Slide the shrink tubing over the joint and apply heat to shrink.

Form the two braid extensions as illustrated and solder to the outside pins.

For a neater appearance, a length of ¼ inch (6mm) shrink tubing can be applied over the exposed braid, but will limit flexibility of the joint.



As always when making connections to a high gain amplifier, shielded coaxial cable should be used on the output (and the input if unbalanced) and the output cable should not be routed near the input.

This completes the assembly and verification of your Z10043A Norton Amplifier.

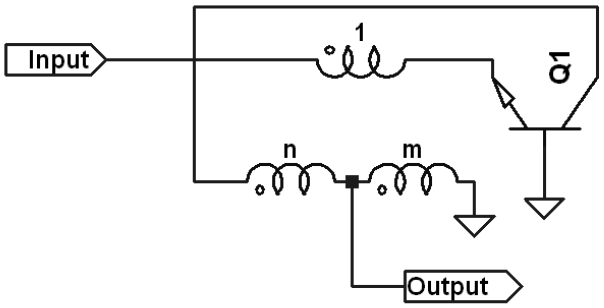
## Schematic and Theory of Operation and Troubleshooting

### Theory of Operation

The Z10043A Norton amplifier consists of two identical amplifier sections arranged in push-pull.

The discussion below uses component designations for the section associated with Q1.

Each section is a common base (also known as "grounded base") amplifier. As such, essentially identical signal currents flow through all three sections of T2 and T1's secondary winding. Gain is achieved in the grounded base amplifier because the collector load, represented by T2's n and m windings operating as an auto-transformer has greater impedance than the emitter input, and hence power gain results.




The figure at the right is a simplified view of an amplifier section, with all DC biasing and blocking components removed so that we may concentrate on the signal flow. The transformer turns ratios are shown as 1:n:m, but this does not mean the emitter feedback winding must have only one turn. Rather, it is the ratio of turns that is important, so that if the emitter winding has, for example, two turns, then the number of turns in windings n and m should also be doubled.

Consider windings n and m and assume a load of impedance Z is connected from output to ground. Windings n and m form an auto-transformer with Q1's collector seeing an impedance of:

$$Z_C = Z_O\left(\frac{n+m}{m}\right)^2$$

Since the same signal current flows through the emitter and collector (neglecting base current), the gain of the common base amplifier is proportional Zc or n and m in this relationship.

The transformer turns ratios should not be arbitrarily selected, if the full benefits of the Norton amplifier are to be realized. From Patent No. 3,891,934, the following equation governs the transformer turns relationship:

$$n = m^2\left(\frac{R_S}{R_L}\right) - m - 1$$

$$n = m^2 \left(\frac{R_S}{R_L}\right) - m - 1$$

Where

$R_S$ is the source (input) impedance

$R_L$ is the load (output) impedance

n and m are the transformer winding ratios, normalized to an emitter winding with one turn.

In our case, we wish the input and output impedances to be equal, and hence $R_S/R_L = 1$. Thus the turns relationship is simplified to:

$n = m^2\text{-}m\text{-}1$

The amplifier's transducer gain[1] is stated as:

$$G_t = m^2 \frac{R_S}{R_L}$$

Again, since our normal operation is with equal input and output impedances, the transducer gain $G_t$ is simply $m^2$.

| Winding Ratio 1:n:m | Transducer Gain (dB) |
|---|---|
| 1:1:2 | 6.0 |
| 1:5:3 | 9.5 |
| 1:11:4 | 12.0 |
| 1:19:5 | 14.0 |
| 1:29:6 | 15.6 |

These figures are theoretical and the actual realizable gain is typically a dB or so less.

In order to extend the low frequency response in the Z10043A, the windings should be doubled; for example, 2:22:8 instead of 1:11:4.

One significant advantage of the Norton amplifier is that the input impedance automatically tracks the output impedance. Thus, if terminated into a 50 ohm load, the input impedance is 50 ohms. If the output impedance is changed to 75 ohms, the input impedance becomes 75 ohms. (This relationship is again not perfect, but it is reasonably good with less than a 2:1 VSWR over the range 300 KHz – 30 MHz when measured in a 50 ohm system.)

DC power is provided to the Z10043A over J3, where it is decoupled with L5, C18 and C19.

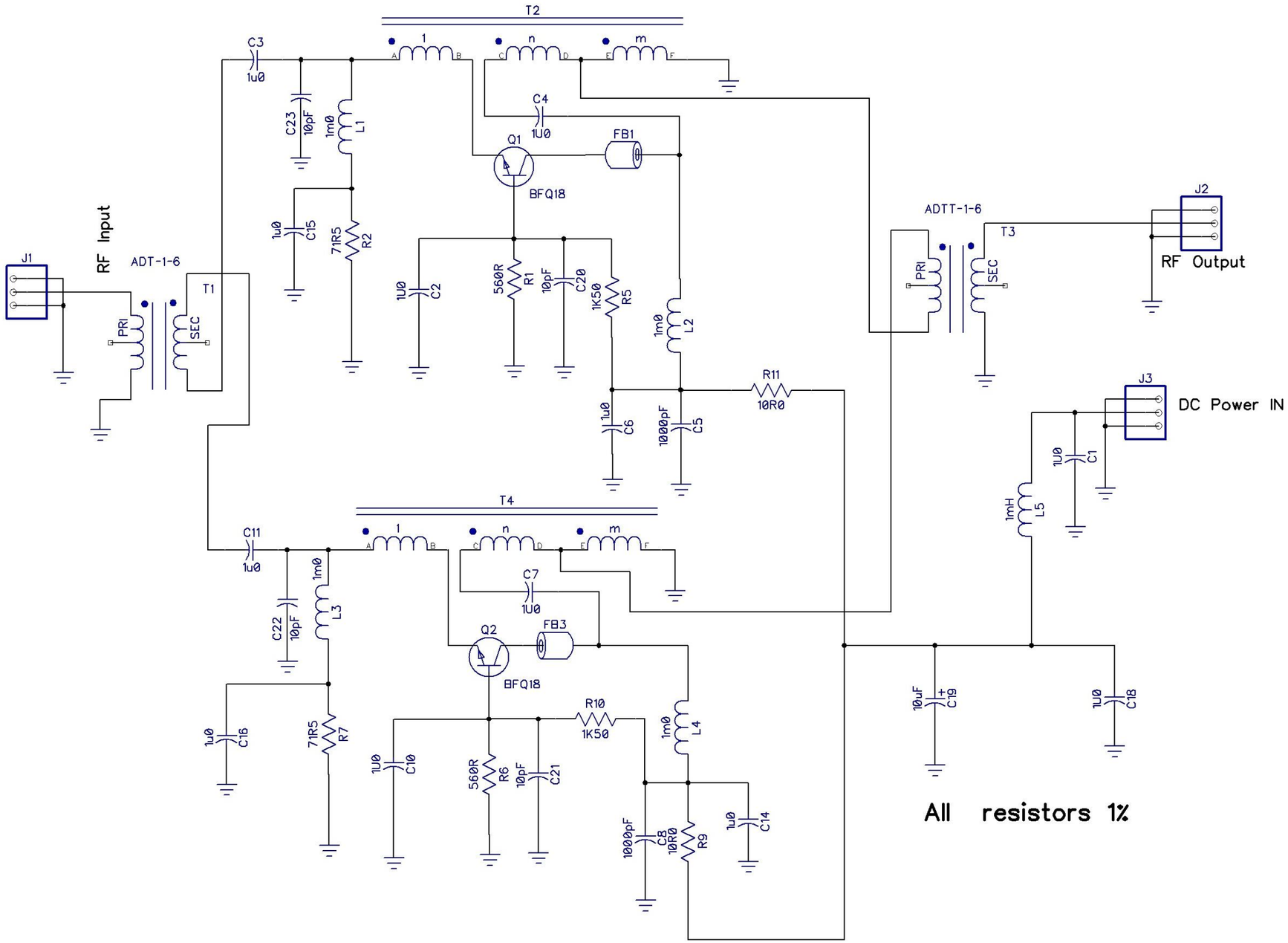
The Z10043A's input and output are through broadband 1:1 transformers.

1 Transducer gain is defined as: "the ratio of the power delivered by a network to a load (PdL) to the power available from the source (Pas). Transducer gain is a function of the source and load reflection coefficients and the network s-parameters." http://www.maurymw.com/support/faqs/faqs/faq9.html

Ferrite beads FB1 and FB3, along with C22 and C23 prevent VHF/UHF parasitic oscillations. (The BFQ18 transistors have appreciable gain above 4 GHz.)

DC power is supplied to Q1 and Q2 through RF chokes L2 and L4, with T2 and T4 output sections being AC coupled by blocking capacitors C4 and C7. There is thus no DC current flowing in T2 and T4's windings, except for the emitter current through the one turn input winding. Removing DC current from T2 and T4 from the majority of the windings reduces core saturation and improves low frequency performance.

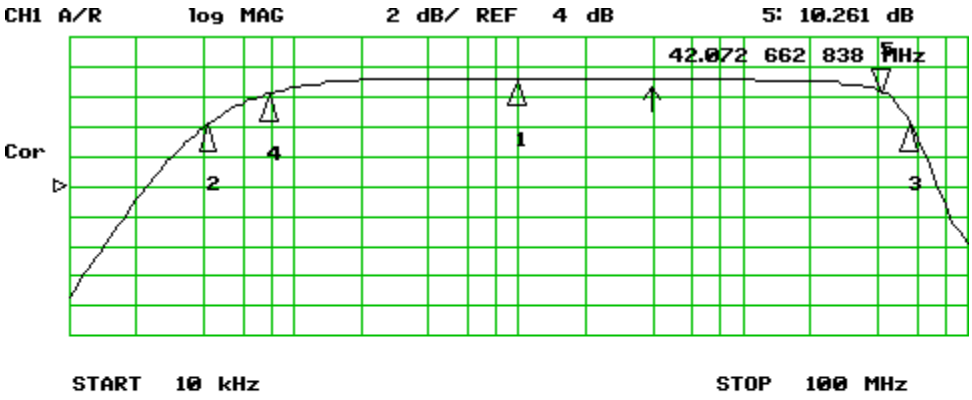
## Schematic


T2
1
n
m
C3
1u0
C23
10pF
1m0
L1
C4
1U0
Q1
FB1
BFQ18
J1
RF Input
ADT-1-6
T1
PRI
SEC
1u0
C15
71R5
R2
1U0
C2
560R
R1
10pF
C20
1K50
R5
1m0
L2
R11
10R0
1u0
C6
1000pF
C5
ADTT-1-6
T3
J2
RF Output
J3
DC Power IN
1u0
C1
1mH
L5
T4
C11
1u0
1m0
L3
C22
10pF
C7
1U0
Q2
FB3
BFQ18
R10
1K50
1u0
C16
71R5
R7
1U0
C10
560R
R6
10pF
C21
1m0
L4
1000pF
C8
10R0
R9
1u0
C14
10uF
C19
1u0
C18
All resistors 1%

## Appendix A Typical Performance Data

All data in this Appendix A is based upon a measured sample of one unit and is presented as typical, not warranted performance.

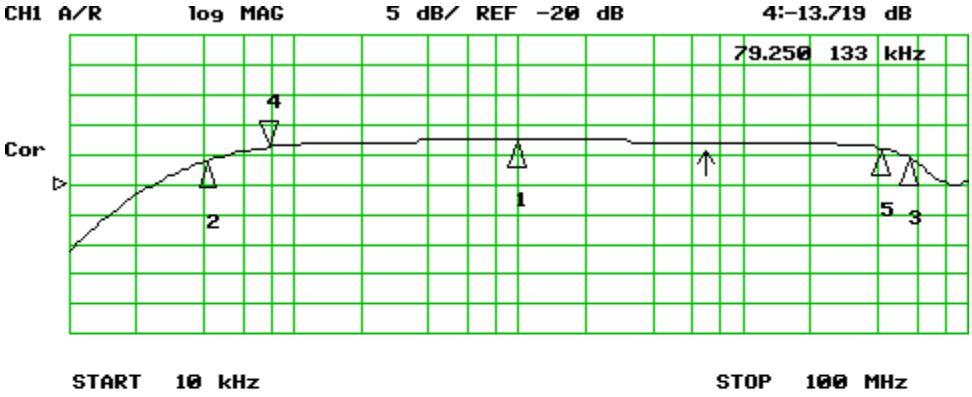
### Bandwidth




| N | STIMULUS | val |
|---|---|---|
| 1 | 1 MHz | 11.262 dB |
| 2 | 42.169 65 kHz | 8.2705 dB |
| 3 | 55.590 425 727 MHz | 8.2553 dB |
| 4 | 79.250 133 kHz | 10.264 dB |
| 5 | 42.072 662 838 MHz | 10.261 dB |

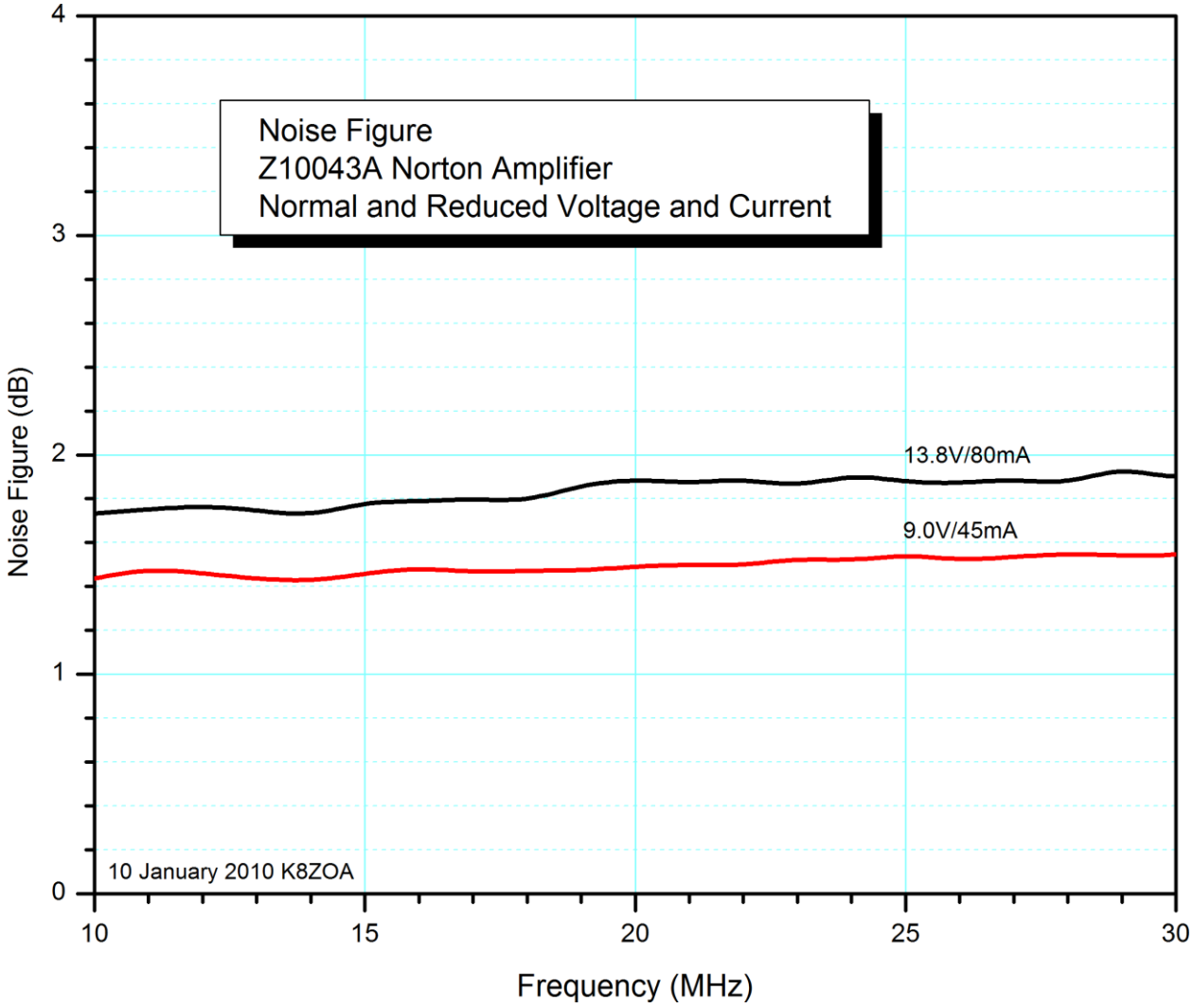
-3 dB bandwidth 42 KHz – 55 MHz; -1 dB bandwidth 79 KHz – 42 MHz.

## Reverse Gain (Isolation)




| N | STIMULUS | val |
|---|---|---|
| 1 | 1 MHz | -12.715 dB |
| 2 | 42.169 65 kHz | -15.853 dB |
| 3 | 55.590 425 727 MHz | -15.729 dB |
| 4 | 79.250 133 kHz | -13.719 dB |
| 5 | 42.072 662 838 MHz | -13.981 dB |

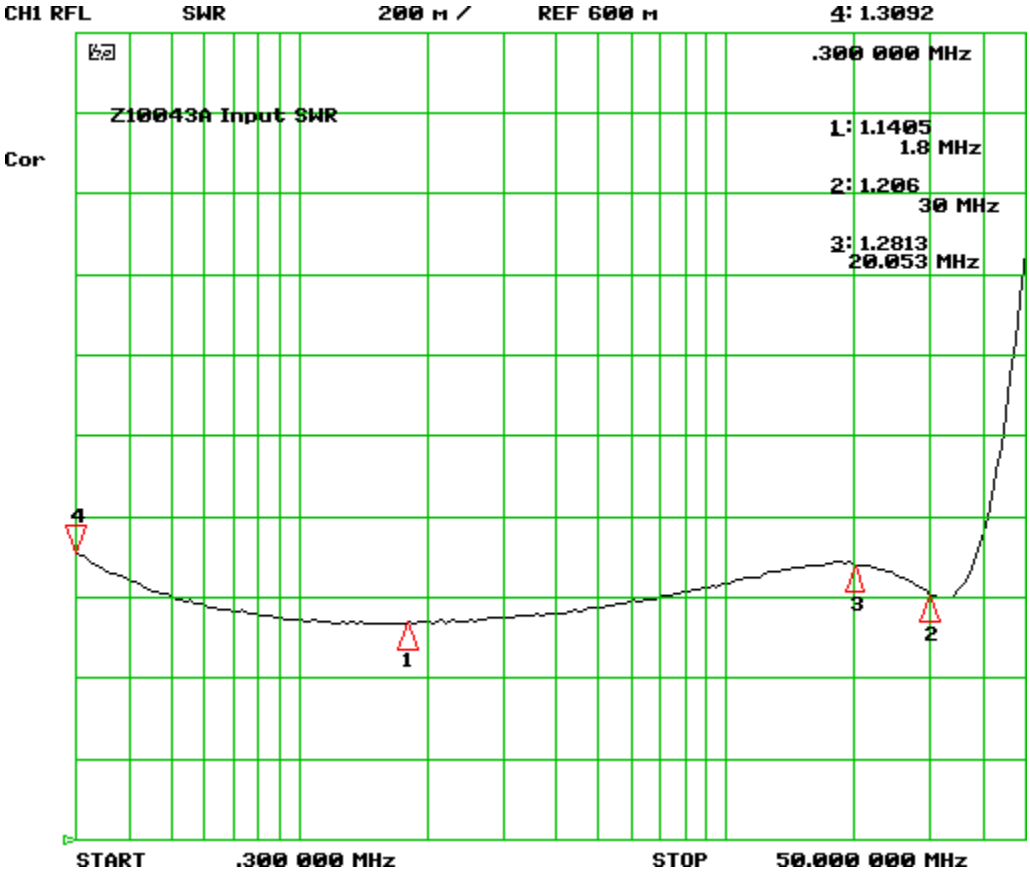
## Noise Figure




The particular Z10043A measured is constructed for 13.8V operation. Improved noise figure results from operating at lower collector current, in this example achieved through reduced operating voltage. However, operating at reduced voltage and/or current will impair 2nd and 3rd order intermodulation performance.

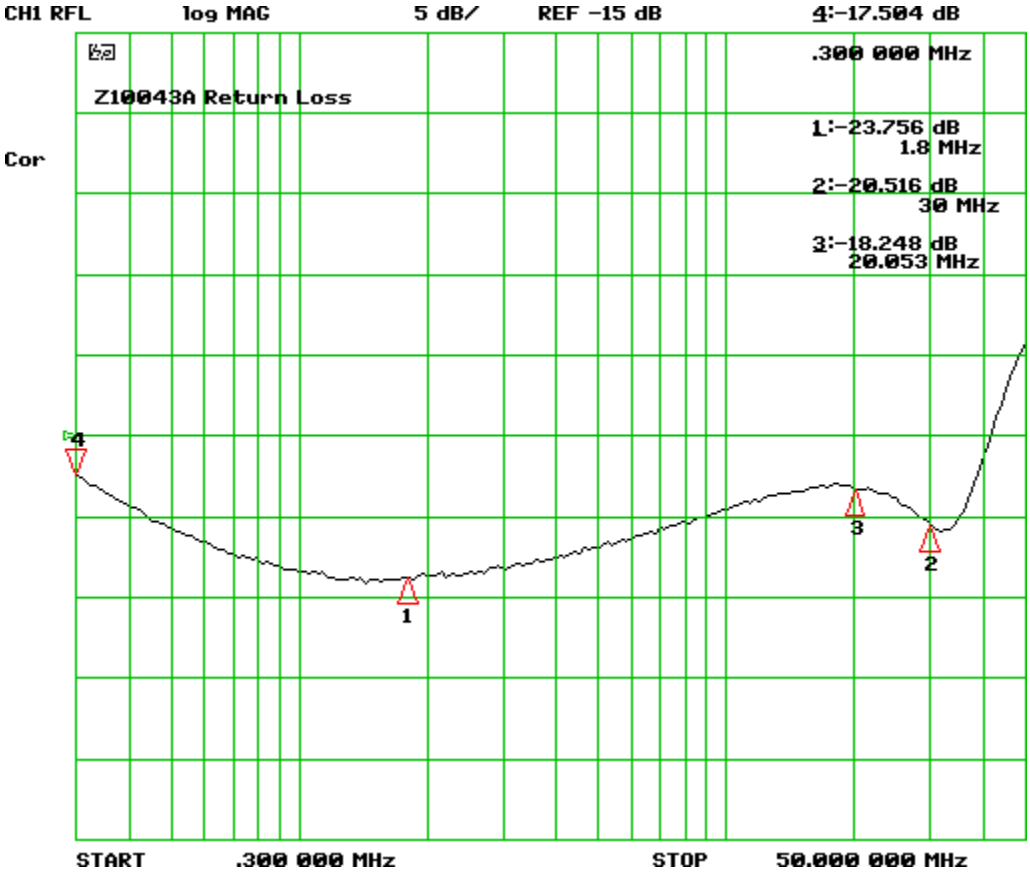
Rated 2nd and 3rd order intercepts are based upon 13.8V/80mA operation.

## Input SWR




Worst case input SWR over range 300 KHz – 30 MHz is 1.3:1.

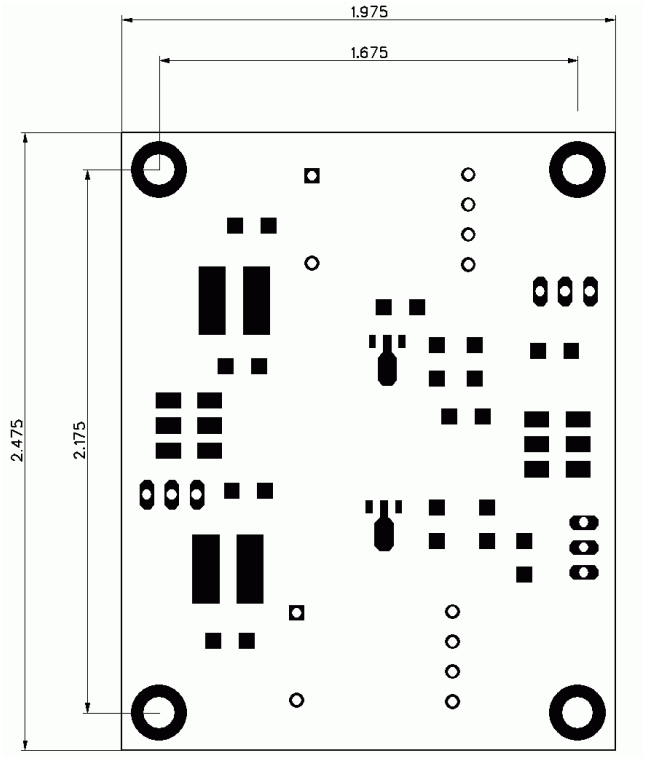
## Input Return Loss

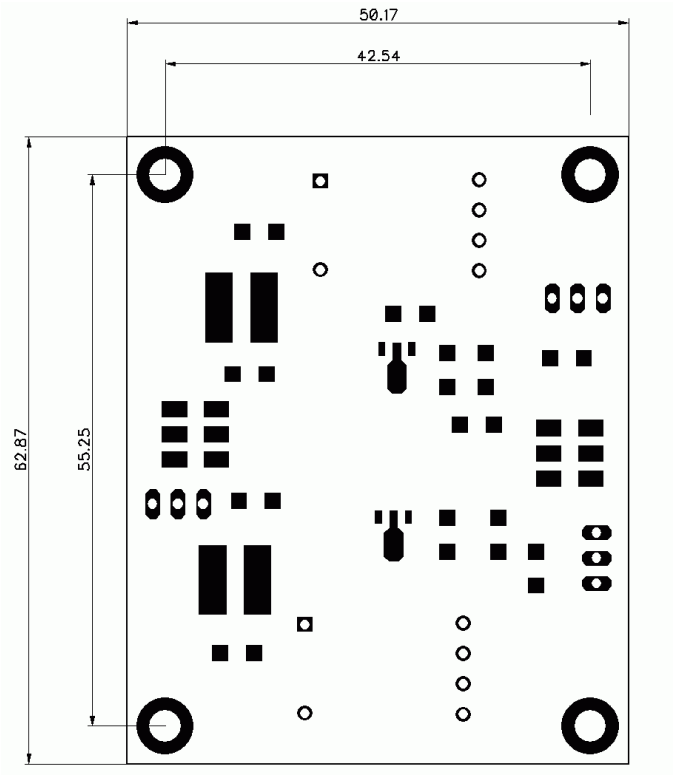



Worst case return loss is -17.5 dB at 300 KHz.

## Appendix B – PCB Mounting Hole Dimensions

Inches above, mm below



## Appendix C – Norton Amplifier Patent, US Patent No. 3,891,934


# United States Patent [19]

**Norton et al.**

[11] **3,891,934**

[45] **June 24, 1975**


[54] **TRANSISTOR AMPLIFIER WITH IMPEDANCE MATCHING TRANSFORMER**


[75] Inventors: **David E. Norton**, Framingham, Mass.; **Allen F. Podell**, Los Altos, Calif.

[73] Assignee: **Adams-Russell Co., Inc.**, Waltham, Mass.



[22] Filed: **May 22, 1974**

[21] Appl. No.: **472,281**

[52] **U.S. Cl.** ..... **330/21**; 330/19; 330/26; 330/165; 330/188; 330/195

[51] **Int. Cl.** ..... **H03f 3/04**

[58] **Field of Search** ..... 330/12, 19, 21, 22, 40, 330/165, 188, 195



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 2,691,077 | 10/1954 | Koros | 330/40 X |
| 2,701,281 | 2/1955 | DeWhite et al. | 330/12 X |



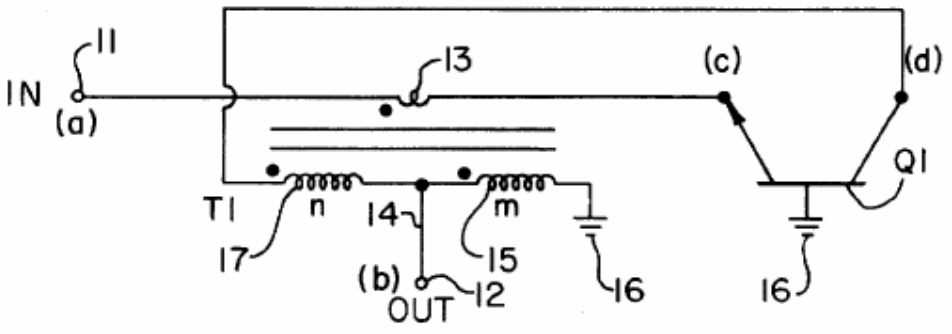
*Primary Examiner*—R. V. Rolinec
*Assistant Examiner*—Lawrence J. Dahl
*Attorney, Agent, or Firm*—Charles Hieken, Esq.; Jerry Cohen, Esq.



[57] **ABSTRACT**

An amplifier includes a transistor and transformer having a primary winding and a tapped secondary winding. The primary winding is connected in series between the input terminal and the transistor emitter. The transistor base and one end of the secondary winding is grounded. The other end of the secondary winding is connected to the transistor collector. The transformer secondary tap is connected to an output terminal. The ratio of that portion of the secondary turns connected between the tap and *r-f* ground and the primary turns is $m$. The ratio of that portion of the secondary turns connected between the tap and the transistor collector and the primary turns is $n$. For two-way impedance match between a source resistance $R_s$ and a load resistance $R_L$, $n = m^2 (R_s/R_L) - m - 1$.


**8 Claims, 5 Drawing Figures**




1

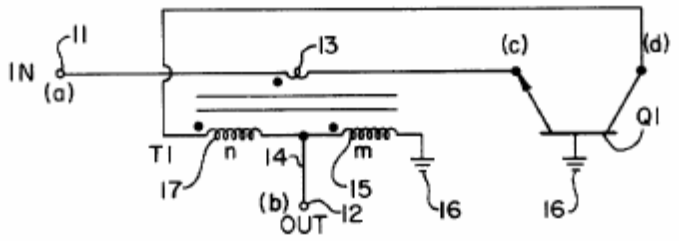



FIG. 1

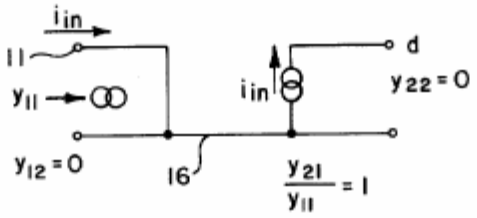



FIG. 2

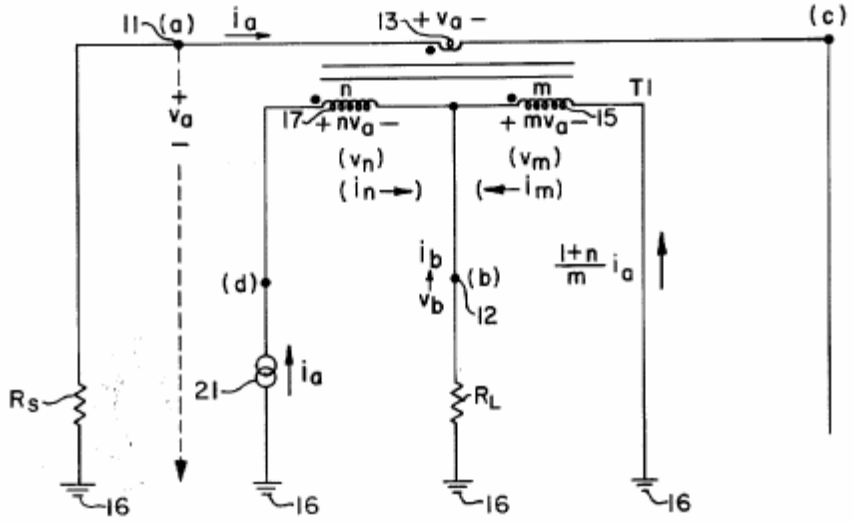



FIG. 3

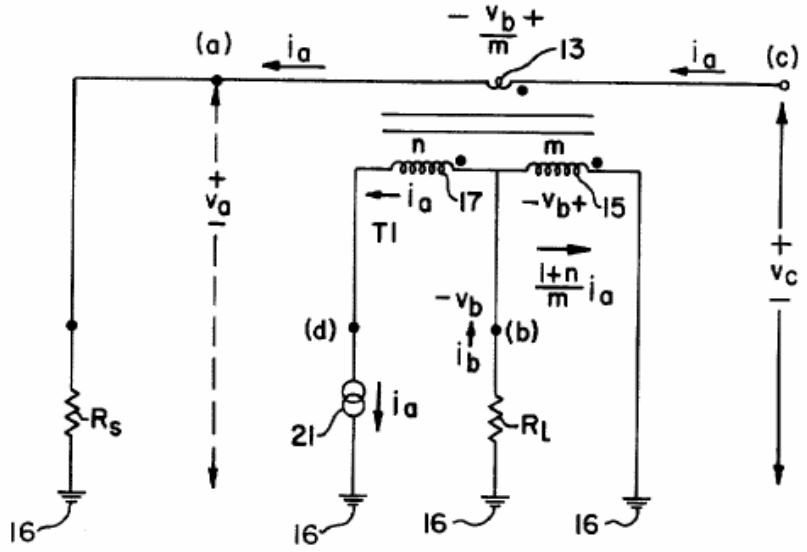

(a)
$i_a$
$-\frac{v_b}{m}+$
13
$i_a$
(c)
n
m
$+v_a-$
$i_a$
17
$-v_b+$
15
T1
$\frac{1+n}{m} i_a$
$+v_c-$
$-v_b$
(d)
(b)
$i_b$
$i_a$
$R_S$
21
$R_L$
16
16
16
16

FIG. 4

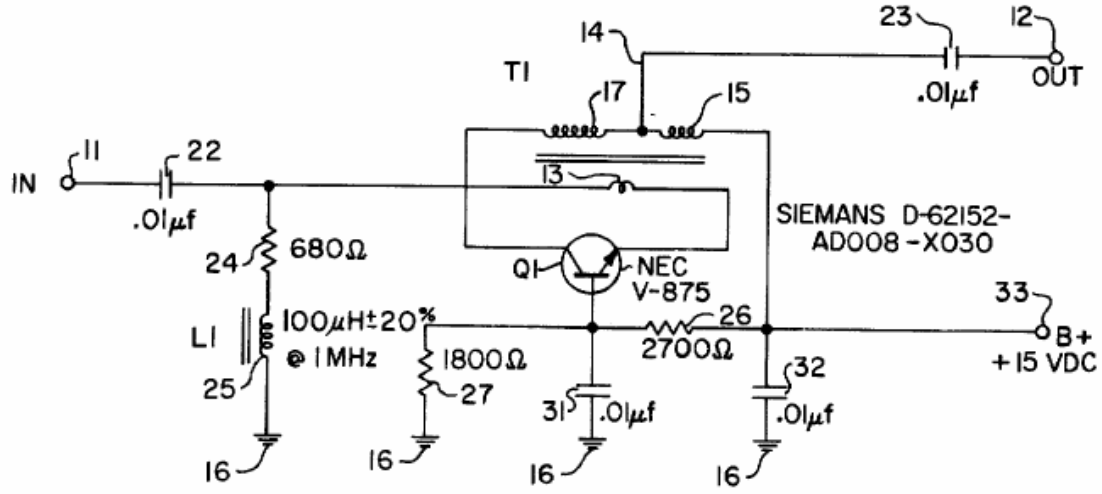

14
23
12
T1
17
15
.01μf
OUT
IN
11
22
13
.01μf
SIEMANS D-62152-
AD008-X030
24
680Ω
Q1
NEC
V-875
33
L1
100μH±20%
@ 1MHz
26
2700Ω
B+
+15 VDC
1800Ω
27
32
25
31
.01μf
.01μf
16
16
16
16

FIG. 5

# TRANSISTOR AMPLIFIER WITH IMPEDANCE MATCHING TRANSFORMER

## BACKGROUND OF THE INVENTION

The present invention relates in general to ampifying and more particularly concerns a novel amplifier with high dynamic range and efficiency especially useful in matching both a source impedance and a load impedance while providing *r-f* amplification over a relatively broad band with a single transformer and single transistor.

CATV coaxial cable systems that transmit and amplify television signals use many amplifiers representing a significant cost of the system. To avoid reflections that cause undesirable visible ghosts on a television screen, care is taken to properly terminate the transmission lines. Thus, both the input and output of an amplifier should match that of the transmission line to which it is connected. While techniques for achieving this result are known, conventional prior art circuits involve many components that are relatively costly to acheive this result.

Still another problem arises from the range of signal levels to be amplified. It is difficult to amplify low level signals adequately and avoid overloading the amplifier with high level signals. Furthermore, dissipation of *r-f* power in amplifying circuit resistors reduces efficiency.

Accordingly, it is an important object of this invention to provide an economical low-noise *r-f* amplifier with high dynamic range and efficiency capable of conveniently matching both a source impedance and a load impedance while providing good amplification over a relatively broad bandwidth.

It is another object of the invention to achieve the preceding object with relatively few components.

It is a further object of the invention to achieve one or more of the preceding objects with relatively few components, none of which need be adjusted once circuit design is complete.

It is still a further object of the invention to achieve one or more of the preceding objects with a circuit that has only one transistor and one transformer.

## SUMMARY OF THE INVENTION

According to the invention, there is an amplifying device having control, input and output electrodes, such as a transistor having at least base, emitter and collector electrodes. Means are provided for effectively connecting at *r-f* the control electrode or base to a common or reference terminal. Transformer means having at least a primary winding and a tapped secondary winding has the primary winding coupled in series between an input terminal and the imput electrode or emitter and its secondary winding effectively coupled between the common terminal and the transistor collector. An output terminal is coupled to a tap between first and second portions of the transformer secondary winding, the first portion being coupled between the tap and the common terminal. The ratio of first portion turns to primary turns is m; of second portion turns to primary turns, *n*. Preferably $n = m^2(R_s/R_L) - m - 1$ where $R_s$ and $R_L$ are the source and load resistances to be matched at the input and output terminals, respectively.

Numerous other features, objects and advantages of the invention will become apparent from the following



specification when read in connection with the accompanying drawing in which:

## BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a schematic circuit diagram of an embodiment of the invention;

FIG. **2** is a representation of the transistor as an ideal common base circuit with various admittance parameters;

FIG. **3** is an equivalent circuit of the circuit of FIG. **1** helpful in understanding the mode of operation;

FIG. **4** is the circuit of FIG. **3** redrawn to help determine the source impedance presented to the emitter; and

FIG. **5** is a schematic circuit diagram of a preferred embodiment of the invention.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

With reference now to the drawing and more particularly FIG. **1** thereof, there is shown a schematic circuit diagram of an embodiment of the invention for providing gain between input terminal **11** and output terminal **12** while matching a source impedance $R_s$ connected to input terminal **11** and a load impedance $R_L$ connected to output terminal **12.** The circuit comprises transistors Q1 and transformer T1. So as not to obscure the principles of the invention the specific means for applying operating and biasing potentials to the particular circuit elements are not shown, those skilled in the art knowing how to supply these potentials. For example, the collector may recieve d-c operating potential through the secondary winding of transformer T1 from a d-c supply bypassed to ground by a suitable capacitor in a manner well-known in the art.

For convenience in the explanation which follows below input terminal **11,** output terminal **12,** the emitter and the collector are designated nodes *a*, *b*, *c* and *d*, respectively. The primary winding **13** is connected between input terminal **11** and the emitter. The secondary winding of transformer T1 has a tap **14** connected to output terminal **12** and a first portion **15** between tap **14** and ground, reference or common terminal **16** and a second portion **17** between tap **14** and the transistor collector. The base of transistor Q1 is effectively connected to ground terminal **16.** The winding polarities are indicated by the dots.

Referring to FIG. **2,** transistor Q1 is represented as an ideal common base circuit having an input admittance $y_{11}$ between base and emitter that is infinite, and output admittance $y_{22}$ between collector and ground that is zero, a reverse transfer admittance $y_{12}$ that is zero and a ratio of forward transfer admittance $y_{21}$ to input admittance $y_{11}$ that is unity.

Referring to FIG. **3,** there is shown an ideal equivalent circuit of the amplifier with a source resistance $R_s$ connected between input terminal **11** and ground **16,** a load resistance $R_L$ connected between output terminal **12** and ground **16,** and transistor Q1 represented as an ideal current source **21** connected between ground **16** and node d delivering the same current $i_a$ into node *d* that enters node a and produces a potential $v_a$ across primary winding **13.** Voltages across portions **17** and **15** and the currents flowing in the various leads are as indicated in FIG. **3.**

The following relationships hold:

$$v_n = nv_a \tag{1}$$

$$v_m = mv_a \tag{2}$$

$$i_a + ni_n = mi_m \tag{3}$$

Since $a$ flows through both the single primary turn and the $n$ turns, then

$$i_m = [(1+n/m\ ]\ i_a$$

With the transformer ideal, and the dependent current generator at node $d$, the following relationships hold:

$$v_b = mv_a \tag{4}$$

$$i_b = -(i_n + i_m)$$

$$i_b = -\ [(m + n + 1)/\mathrm{m}]\ i_a \tag{5}$$

Hence

$$v_b\, i_{\ a} = -\ (m + n + 1)\ i_n v_a \tag{6}$$

$$v_b/i_b = -\ [m^2/(m+n+1)]\ v_a/i_a \tag{7}$$

With a voltage source in series with source resistance $R_s$, $i_b$ flows outward into $R_L$, and

$$v_b/i_b = -R_L \tag{8}$$

Hence from (7)

$$v_a/i_a = [(m\ +n\ +1)/m^2\ ]\ R_L = R_{in} \tag{9}$$

With a voltage source in series with $R_L$, $i_a$ flows outward into $R_s$, and

$$v_a/i_a = -R_s \tag{10}$$

Hence from (7)

$$v_b/i_b = [m^2/(m+n+1)]R_s = R_{out} \tag{11}$$

The input impedance matches the source resistance $R_s$ if $m$ and $n$ are related by

$$R_{in} = R_s = [(m+n+1)/m^2]R_L \tag{12}$$

If this expression for $R_s$ is substituted in equation (11), $R_{out} = R_L$, the desirable situation of two-way impedance match. Rewriting equation (12) to relate $m$ and $n$ for two-way impedance match,



$$n = m^2(\mathrm{R}_s/\mathrm{R}_L) - m - 1 \tag{13}$$

Note that if $m$ is an integer and $R_s$ and $R_L$ are related so that $m^2(R_s/R_L)$ is also an integer, then $n$ will also be an integer.

It is assumed that equation (13) is satisfied from here on. With a voltage source, $v$, in series with $R_s$, then the available power at the input is

$$P_{av_a} = v^2/4R_s \tag{14}$$

But with equation (13) satisfied, the input is matched and

$$v_a = v/2 \text{ and } P_{av_a} = v_a i_a \tag{15}$$

The power delivered to the load at node $b$ is

$$P_b = -v_b i_b = (m+n+1)\ P_{av_a} \tag{16}$$

The transducer gain G is the ratio of:

$$P_b/P_{av_a} = G = m+n+1 = m^2(R_s/R_L) \tag{17}$$

Likewise with the generator at node $b$ we have

$$P_{av_b} = v^2/4R_L,\ v_b = v/2 \text{ and } v_b i_b = P_{av_b}$$

Hence:

$$P_a = -v_a i_a = [1/(m+n+1)]P_{av_b} \tag{18}$$

and the reverse gain $G_r$ is given by

$$P_a/P_{av_b} = G_r = 1/G \tag{19}$$

With the source at node a the load impedance, $R_{Lc}$, presented to the collector is

$$R_{Lc} = v_a/i_a = [(n+m)\ v_a]/i_a \tag{20}$$

but $v_a/i_a = R_s$. Hence:

$$R_{Lc} = (n+m)\ R_s \tag{21}$$

Referring to FIG. **4**, the equivalent circuit of FIG. **3** is redrawn to facilitate determining the source impedance presented to the emitter as seen looking in at the emitter feed point between node c and ground **16**. Assuming that node c is positive with respect to ground, the voltages and currents are as indicated in FIG. **4** and the following relationships occur.

$$R_{sc} = v_c/i_n = [v_a+(v_2/m)]/i_a \tag{22}$$

$$v_a = i_a R_s;\ v_b = i_b R_L \tag{23}$$

$$i_b = [(m+n+1)/m]i_a \quad (24)$$

Hence:

$$R_{ae} = R_s + [(m+n+1)/m^2]R_L \quad (25)$$

But comparing equation (12) with equation (25) shows that

$$R_{ae} = 2R_s \quad (26)$$

In summary for two-way impedance match the following relationships occur:

| | | |
|---|---|---|
| Turns Ratio: | $n = m^2 (R_s/R_L) - m - 1$ | (13) |
| Forward Gain: | $G = m^2 (R_s/R_L)$ | (17) |
| Reverse Gain: | $G_r = 1/G$ | (19) |
| Collector Load Impedance: | $R_{Lc} = (n+m) R_s$ | (21) |
| Emitter Source Impedance: | $R_{se} = 2R_s$ | (26) |

Referring to FIG. **5**, there is shown a schematic circuit diagram of a preferred embodiment of the invention showing typical parameter values. The same reference symbols identify corresponding elements throughout the drawing. FIG. **5** includes an input coupling capacitor **22**, an output coupling capacitor **23**, an emitter biasing resistor **24** in series with an *r-f* choke **25**, biasing resistors **26** and **27**, bypass capacitors **31** and **32** and B+ terminal **33**. The circuit dissipates negligible *r-f* power. Resistors **24**, **26** and **27** do not dissipate *r-f* power because negligible *r-f* current flows through them. Were transformer **T1** and transistor **Q1** ideal and lossless, there would be essentially no *r-f* power loss between input and output. Because of the nature of the circuit, the circuit dynamic range corresponds substantially to that of transistor **Q1**.

With the circuit of FIG. **5** and **10** ma. delivered into terminal **33** at 15 volts, the invention had a gain of 8dB± 0.25 dB from 5 to 350 MHz. For input and output impedance of 50 ohms the maximum VSWR was 1.5 from 5 to 100 MHz and 2 from 100 to 250 MHz. The maximum noise figure was 1.2 dB from 5 to 150 MHz and 1.5 dB from 150 to 200 MHz. The minimum power output at 1dB compression over 5 to 150 MHz was 10 dBm and from 150 to 200 MHz **9** dBm.

There has been described a novel *r-f* amplifying circuit characterized by matching source and load impedances and good amplification over a relatively broad bandwidth while using relatively few components, components that need not be adjusted and are relatively economical. It is evident that those skilled in the art may now make numerous uses and modifications of and departures from the specific embodiments described herein without departing from the inventive concepts. Consequently, the invention is to be construed as embracing each and every novel feature and novel combination of features present in or possessed by the apparatus and techniques herein disclosed and limited solely by the spirit and scope of the appended claims.

What is claimed is:

**1.** Amplifying apparatus comprising,
amplifying means having at least control, input and output electrodes,
a common terminal,
transformer means having at least a primary and a secondary winding,
said secondary winding having a tap intermediate to first and second portions thereof,
an input terminal,
an output terminal,
means for coupling said output terminal to said tap,
means for coupling said primary winding between said input terminal and said input electrode,
said first portion being coupled between said tap and said common terminal,
said second portion being coupled between said tap and said output electrode,
and means for coupling said control electrode to said common terminal.

**2.** Amplifying apparatus in accordance with claim **1** wherein the turns ratio between said first portion and said primary winding is m and between said second portion and said primary winding is n with $n = m^2 R_s/R_L - m - 1$ wherein $R_s$ is a predetermined source resistance and $R_L$ is a predetermined load resistance.

**3.** Amplifying apparatus in accordance with claim **2** and further comprising said source resistance coupled between said input terminal and said common terminal and said load resistance coupled between said output terminal and said common terminal.

**4.** Amplifying apparatus in accordance with claim **1** wherein said amplifying means comprises a transistor and said control, input and output electrodes comprise base, emitter and collector electrodes, respectively.

**5.** Amplifying apparatus in accordance with claim **4** and further comprising,
a source of d-c operating potential connected to said collector electrode through said secondary winding,
and means for biasing said base and emitter electrodes.

**6.** Amplifying apparatus in accordance with claim **5** wherein the means for biasing said base electrode comprises a first resistor connected between said source of d-c potential and said base electrode and a second resistor connected between said base electrode and said common terminal and the means for coupling said base electrode to said common terminal comprises an *r-f* bypass capacitor and further comprising,
another *r-f* bypass capacitor coupling said source of a d-c potential to said common terminal.

**7.** Amplifying apparatus in accordance with claim **6** wherein said means for biasing said emitter electrode comprises an emitter biasing resistor in series with an *r-f* choke between said common terminal and said primary winding.

**8.** Amplifying apparatus in accordance with claim **7** wherein said means for coupling said primary winding between said input terminal and said emitter electrode comprises a capacitor and said means for coupling said output terminal to said tap comprises a capacitor.

* * * * *

## Appendix D Manual Backdating

There are no manual backdating pages.