# HIGH POWER ALL BAND LINEAR

## INTRODUCTION

The Matco Electronics High Power All Band Linear Amplifier #233 is adaptable to any frequency band from 1.6 MHZ to 50 MHZ by constructing the proper input and output matching transformers. The design features automatic antenna switching and automatic power up/power off relay switching in order to work well with all types of radio transceivers. RF power from the transceiver is detected, rectified and used to control the relay functions. As an added feature, output power can be tailored to your use by the choice of power transistors used in your project. The amplifier "boards" may also be ganged to increase power output; the output from one board goes to the input of the next, etc. See figure two.

The transceiver used to drive this linear should be capable of at least 1.5 watts of RF power. The linear output level may also be controlled by limiting the drive level from the transceiver.

## CIRCUIT DESIGN

Failure to follow the specified layout of this linear or the use of unspecified parts or components may result in inefficient or unstable operation. Refer to the schematic (fig.1), RF input from the transceiver is detected by the relay switching circuit controlling $K_1$. The detected RF closes 12 volt relay $K_1$ which then applies +12VDC to a bias regulating power supply and the collectors of $Q_1$ and $Q_2$. the antenna relay $K_2$ is also closed by the application of 12 VDC to it. If only one amplifier board is used, a second antenna relay $K_3$ is also closed, completing the circuit through an antenna matching network. If a second board is used, the output from board one is connected to the input of the second board. Only one power switching relay $K_1$ is used regardless of how many boards are used. Also, only one input antenna relay $K_2$ and one output antenna relay $K_3$ are used regardless of how many boards are ganged together. Each board must be equipped with its own bias power supply however.

Referring to the schematic diagram again, RF appearing at $K_2$ is coupled via $D_1$ and $R_1$ to a reversed diode $D_2$ and a capacitor $C_1$ thus rectifing the detected RF. This rectified RF is then fed through $R_2$ to act as a control bias on the base of $Q_3$ which in turn is activated and closed power relay $K_1$. The normally open contacts of $K_1$ close and thus apply +12 VDC to all power transistor collectors (through RF chokes $L_2$ and primaries of $T_2$. +12 VDC is also applied to the bias control $IC_1$ and to each of the antenna switching relays $K_2$ and $K_3$ which then close, bypassing the RF power through the amplifier circuit.

The bias circuit $IC_1$ is a 3 terminal 5 volt voltage regulator which has its return terminal connected to ground via a 250 ohm potentiometer, thus allowing the output voltage of the regulator to be controlled from 5 to 6 volts. The output of the regulator is passed through a 5.1 volt Zener diode which drops the voltage to a range of .1 to 1 volt. This bias voltage is then passed through another RF choke $L_1$ to the center tap of the secondary coil of matching transformer $T_1$.

When antenna relay $K_2$ closes, RF is applied to the primary winding of $T_1$. The secondary coil of $T_1$ is a center tapped winding which thus provides two signals, each 180 degrees out of phase from each other. These signals are then passed to the bases of power transistors $Q_1$ and $Q_2$. The collectors of the power transistors pass the amplified RF to the primary coils of $T_2$. $T_2$ raises the impedance to 50 ohms for matching to either the next amplifier board or to the antenna matching network $C_3$, $C_4$ and output relay $K_3$. The center tap of the primary winding of $T_2$ is fed B+ (12 VDC) through RF choke $L_2$.

As was mentioned earlier, your choice of power transistors will control the power output from this amplifier circuit.

Use Motorola MRF421 or a 2N5008 for up to 250 watts output.

Use Motorola MRF454 or a 2N500 for up to 180 watts.

Use Motorola MRF460 for up to 100 watts.

Use Motorola MRF452 for up to 50 watts.

If this board will be used to drive another linear stage, about 25 watts output will be sufficient from the first stage, and the MRF452's would be a good choice. Bias current is calculated by using the formula $I_c$/hfe, as this current will allow the transistors to operate at the optimum point on their curve. ie. presuming an operating efficiency of 50% and a hfe of 30, the bias current for the MRF421 power transistor would be 1.38 amperes.

# BUILDING TIPS

All parts are mounted on a 6" square piece of copper clad fiberglass PC board as shown in figure 9, inside of a metal cabinet(such as our #LMB 146).

Two holes ½" diameter are drilled in the board to clear the transistor bodies. Four ¼" holes are drilled for connecting wires to the transistor base and collector terminals, and four 1/16" holes are drilled for the emitter connecting wires. Use the pattern in figure three to properly position the transistor mounting holes in the PC board.

The power transistors will mount to the heat sink plate through 1" clearance holes in the cabinet base. The patterns for the holes in the cabinet base and heat sink plate are shown in figures four and five. Eight 1" long pieces of #12 solid copper wire are cut and bent as in figure six and soldered to the transistor tabs as in figure seven.

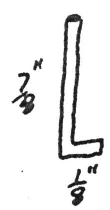


FIGURE SIX
TRANSISTOR CONNECTOR WIRES

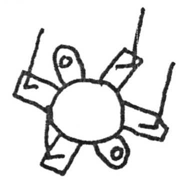


FIGURE SEVEN

These wires will pass through the holes in the PC board.

RF chokes $L_1$ and $L_2$ are wound on ¼" diameter fiberglass rod. The number of turns on the RF chokes will be ½ the number of turns of the transformer winding it will be connected to.

Matching transformers $T_1$ and $T_2$ are wound on ½" diameter fiberglass tubing about 1" in length. Four L shapped brackets made from plastic (such as old toothbrush handles) are heated and bent about 1" high by ½" on the foot. Use epoxy cement to fasten the legs onto the fiberglass tubes as in figure eight.

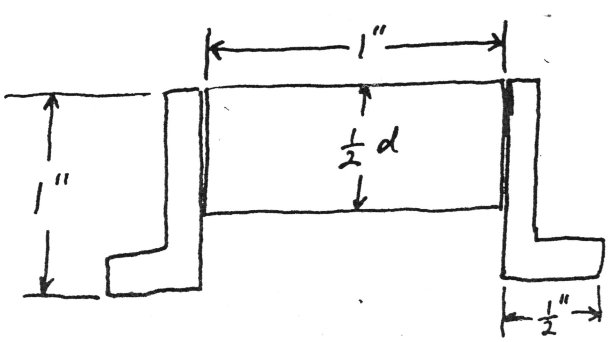


FIGURE EIGHT
TRANSFORMER FORMS

The number of turns used for $T_1$ and $T_2$ is determined by the frequency the linear will be used on. Chart A following, illustrates the range of frequency bands and coil turn information.

CHART A

| $T_1$ | 5 MHZ | 27 MHZ | 50 MHZ |
|---|---|---|---|
| PRIMARY | 70 turns | 46 turns | 21 turns |
| SECONDARY | 194 turns, center tapped | 127 turns, C.T. | 60 turns, C.T. |

| $T_2$ | 5 MHZ | 27 MHZ | 50 MHZ |
|---|---|---|---|
| PRIMARY | 38 turns, center tapped | 24 turns, C.T. | 10 turns, C.T. |
| SECONDARY | 70 turns | 46 turns | 22 turns |

ALL WINDINGS #26 FORMVAR MAGNET WIRE ON ½" OD FORM, 1" LONG.

All parts for the RF detector circuit may be soldered to a 6 lug terminal strip as shown in figure nine. The parts for the bias voltage supply circuit may, likewise, be soldered to a terminal strip, but with 5 lugs as shown in figure ten.

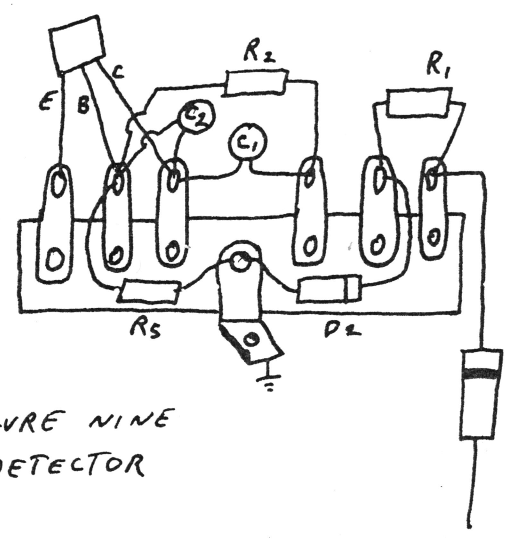


FIGURE NINE
: DETECTOR

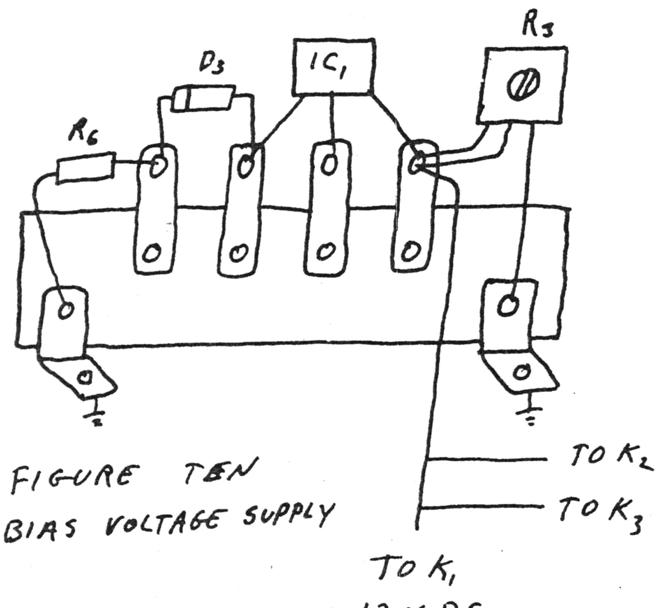


FIGURE TEN
BIAS VOLTAGE SUPPLY

A piece of copper clad PC board is positioned vertically over the center line of $Q_1$ and $Q_2$ to act as an RF shield to seperate the input sides from the output sides of the circuit. The shield will be soldered at 3/4" intervals along its entire length.

## CONSTRUCTION STEPS

Cut copper clad PC board to size.
Drill all holes in PC board according to figure three.
Drill clearance holes in cabinet base according to figure four.
Drill holes in heat sink plate according to figure five.
Fasten heat sink strips to heat sink plate by drilling and tapping plate for small machine screws. Use about 6 screws per strip to insure good thermal conductivity. Coat each heat sink strip with heat sink compound when mounting them.
Mount cabinet base to heat sink plate by drilling a hole in the center of each edge and tapping the plate for small machine screws.
Coat the transistor bottoms with heat sink compound and mount the transistors to the heat sink plate with 4-40 x 3/8" machine screws. Make sure the collector tabs (the ones with the corner cut on an angle) are oriented toward $T_2$ side of the cabinet.
Solder components for RF detector circuit and bias supply to their terminal strips.
Mount the terminal strips to the PC board with #6-32 machine screws. Pass the screws from the bottom of the board up, with the nuts on top.
Wind RF chokes $L_1$ and $L_2$ on ¼" fiberglass rod. $L_1$ is wound with #24 magnet wire using ½ the number of turns of the secondary coil of $T_1$. $L_2$ is wound with #16 magnet wire using ½ the number of turns of the primary winding of $T_2$.
Construct the forms for $T_1$ and $T_2$. Wind and mount the transformers on the PC board using epoxy cement.
Place the PC board over the transistor leads to make sure they all line up properly and mark the corner holes in cabinet base for mounting the PC board.
Remove the PC board, drill and tap the four holes in the cabinet base and heat sink plate for small machine screws.
Peposition PC board over transistor leads. Place short lengths of teflon sleeve insulation over the base and collector leads to make sure they will be insulated from the PC board. (insulators from TO-3 transistor mounting kits work well)

Use #6-32 nuts or other spacers under each corner of the PC board to space the board evenly above the cabinet base and mount the PC board to the cabinet.

Pull up gently on the emitter leads so they will be against the bottom of the PC board and solder the emitter leads to the top side of the PC board.

Gently pull up on the collector leads of the power transistors and solder the primary leads of $T_2$ to these collector leads.

Pull up the base leads of the power transistors and solder the secondary leads of $T_1$ to these base leads.

Make sure neither the collector leads or base leads short out to the PC board.

Solder center tap of $T_1$ to $L_1$. Solder other end of $L_1$ to bias lug #1.

Solder center tap of $T_2$ to $L_2$. Solder other end of $L_2$ to bias lug #4.

Drill holes and mount coax connectors $J_1$ and $J_2$ to rear of cabinet.

Mount $K_1$, $K_2$ and $K_3$ to front of cabinet. Use epoxy cement and mount with terminals up.

Keeping leads as short as possible, connect $K_2$ as follows:

One side of $K_2$ coil to normally open contacts of $K_1$.

Other side of $K_2$ coil to copper clad (ground)

Normally open contact of $K_2$ to $T_1$ primary Use RG8U coax and ground shield.

Other side of $T_1$ primary soldered to copper clad (ground)

Arm contact of $K_2$ to input coax connector. Use RG8U coax and ground shield.

If you are only using one amplifier board, mount capacitors $C_3$ and $C_3$ on the circuit board. Use epoxy cement and mount them on their edge. This is shown in the parts layout diagram. If your are using more than one amplifier stage, forget $C_3$ and $C_4$ for now and mount them on the last board in the series.

Keeping leads as short as possible, connect $K_3$ as follows:

One side of $K_3$ coil to normally open contacts of $K_1$.

Other side of $K_3$ coil to copper clad (ground).

Normally open contacts of $K_3$ to $C_4$.

$C_3$ will be soldered to primary of $T_2$.

Other side of $T_2$ is soldered to copper clad (ground).

Arm of $K_3$ to $J_2$ output coax connector. Use RG8U coax and ground shield.

Connect a length of coax from normally closed contacts of $K_2$ to normally closed contacts of $K_3$. Ground both ends of shield.

Connect $K_1$ as follows:

One side of $K_1$ coil to unswitched 12 volts. Use #10 wire.

Other side of $K_1$ coil to collector lug of $Q_3$.

One normally open contact to side of coil where unswitched 12 volts is connected.

One normally open contact to $IC_1$ and $L_2$.

Solder power source negative to copper clad (ground)

Connect and solder capacitors $C_5$ and $C_6$ to to $L_1$ and $L_2$. Ground other ends of the capacitors.

With sheet metal or sheet aluminum, build a cover over the heat sinks. See figures eleven and twelve. Make the front of the cover larger than the heat sinks to form an air channel. Mount a blower at the rear of the linear and connect it so it will blow fresh air through the sheet metal cover and over the heat sinks. The blower power leads should be connected to the power source so that it will blow whenever the linear is on.

## INSTALLATION AND ADJUSTMENTS

When your linear is completed and ready to power up, connect the transceiver and antenna leads to the proper coax connectors.

Remove the lead from between $L_2$ and lug #4 of the bias terminal strip where it connects. Place a 100 mA meter in series with a 100 ohm potentiometer in place of this wire. This is to measure the transistor collector current.

Turn the power switch on and either manually close the contacts of $K_1$ or place a jumper lead across the terminals. Adjust the bias pot $R_3$ for a collector current of 50 mA with no RF drive.

Remove jumper from $K_1$, remove meter and 100 ohm resistor and resolder the wire from $L_2$ to the terminal lug.

Now you are ready to tune the linear output. You should have a wattmeter connected between the linear and the antenna. Key the transceiver briefly and make sure all relays function properly.

Now key up again and quickly adjust $C_3$ until the highest reading is obtained on the wattmeter. Apply RF only briefly during these first stages of tuning and make adjustments as quickly as possible.

Key up again and adjust $C_4$ to obtain highest wattage reading.

Work back and forth between $C_3$ and $C_4$ until no further increase in wattage is realized. Your linear should now be tuned and ready for service.

## ~~#233~~ 1005 PARTS LIST

| | | |
|---|---|---|
| $Q_1$, $Q_2$ | | MRF 421 Power Transistor, $69.95 |
| | -or- | MRF 454 Power Transistor, $27.95 |
| | -or- | MRF 460 Power Transistor, $33.30 |
| | -or- | MRF 452 Power Transistor, $37.75 |
| $Q_3$ | | MPS A13, NPN Darlington transistor, $.99 |
| $IC_1$ | | 5 volt regulator IC, Radio Shack #RS7805-T |
| $D_1$, $D_2$ | | 1N4001 diode, $.15 |
| $D_3$ | | 1N4733 Zener diode, 5.1 volt, $.40 |
| $C_1$, $C_2$ | | .005 uf, 25 volt, $.24 |
| $C_3$, $C_4$ | | 2.4 - 24.5 pf, trimmer capacitor, $1.62 |
| $C_5$, $C_6$ | | .1 uf, 100 volt disc, $.40 |
| $R_1$, $R_2$ | | 4.7 K ohm, ¼ watt, $.12 |
| $R_3$, $R_4$ | | 500 ohm potentiometer, ½ watt, $1.49 |
| $R_5$ | | 10 K ohm, ¼ watt, $.12 |
| $R_6$ | | 47 ohm, 1 watt, $.20 |
| $K_1$ - $K_3$ | | SPDT relay, 12 VDC, #SC003, $4.99 |

MISCELLANEOUS

6 lug terminal strip #825, $.30

5 lug terminal strip, #822, $.25

Chassis #LMB 146, $11.34

Heat sink plate, 8" x 6" x ¼" aluminum

Four heat sink strips, #233HSS, $4.50

Copper clad circuit board, 6" x 9" and 3" x 6", $3.99

Cooling fan, 12 volt radial type

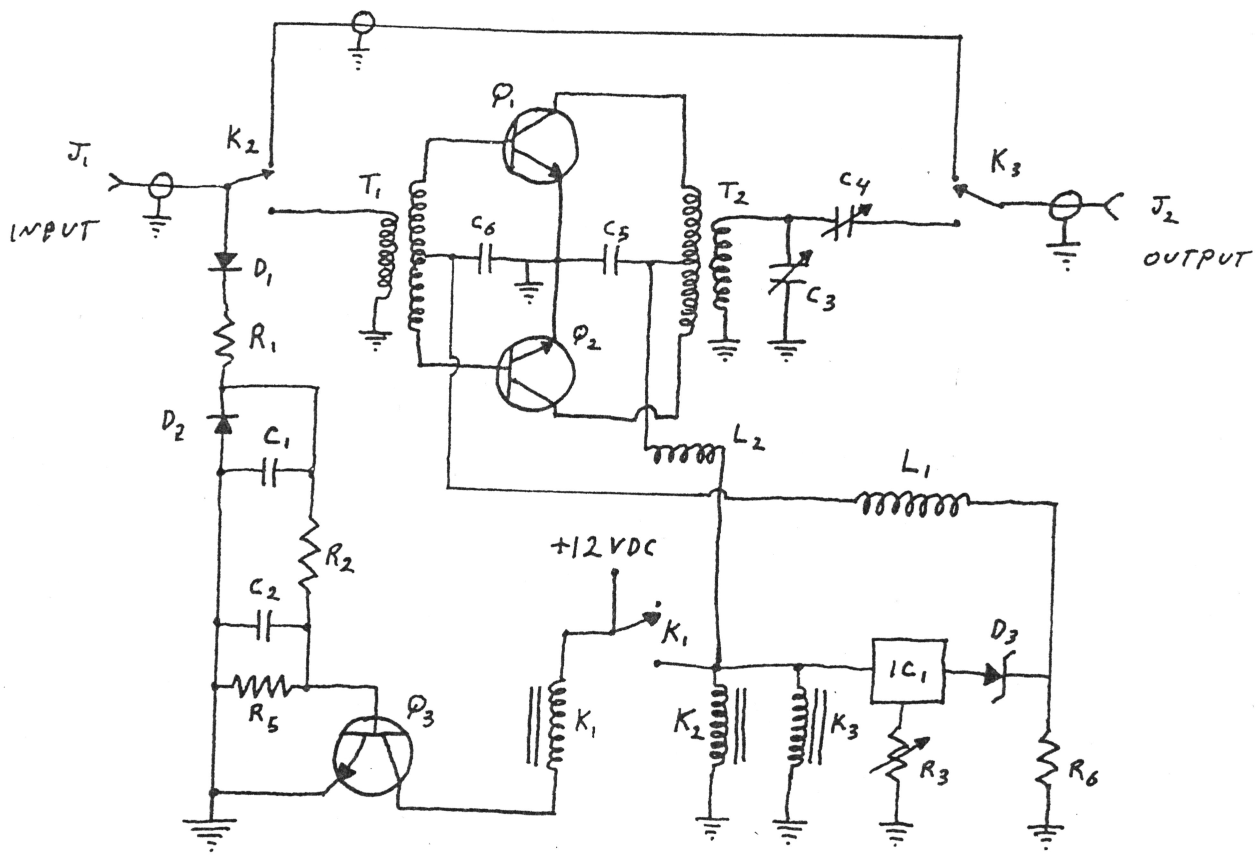


FIGURE ONE

LINEAR SCHEMATIC DIAGRAM

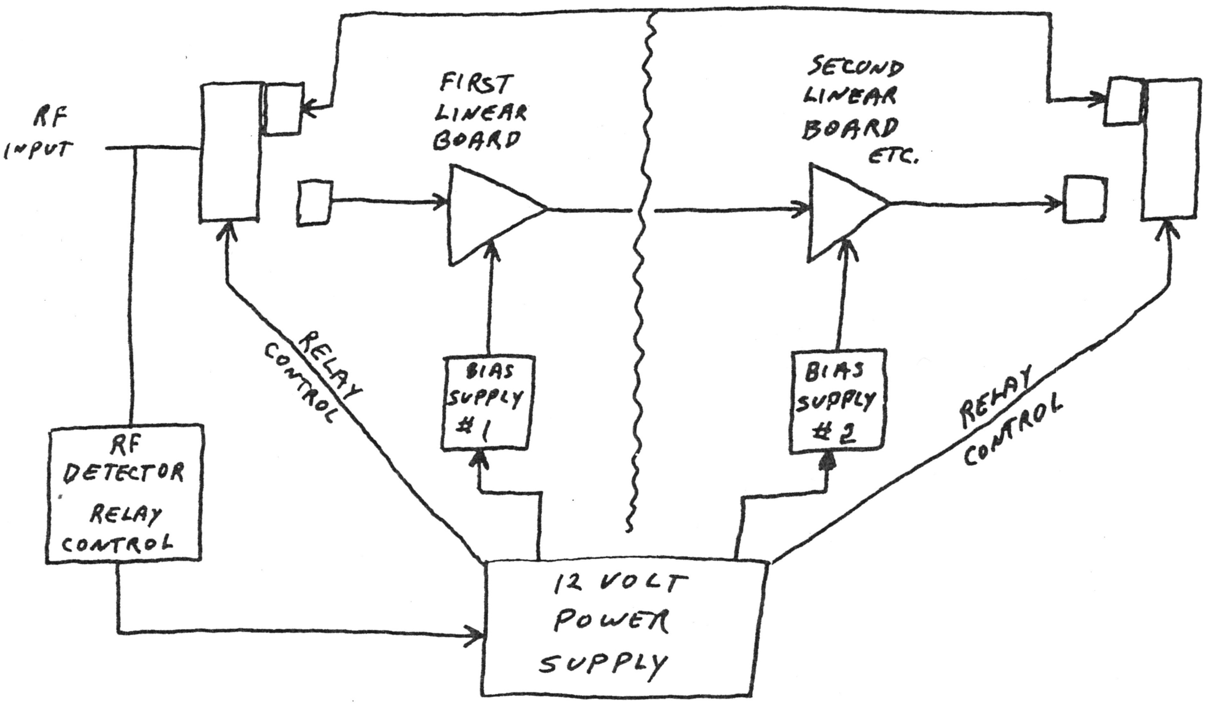


FIGURE TWO

BLOCK DIAGRAM ILLUSTRATING THE GANGING OF LINEAR BOARDS

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## The RF Line
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**MRF455**

. . . designed for power amplifier applications in industrial, commercial and amateur radio equipment to 30 MHz.

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  Minimum Gain = 13 dB
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**60 W, 30 MHz
RF POWER
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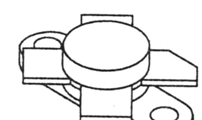

CASE 211–07, STYLE 1

### MATCHING PROCEDURE

In the push–pull circuit configuration it is preferred that the transistors are used as matched pairs to obtain optimum performance.

The matching procedure used by Motorola consists of measuring $h_{FE}$ at the data sheet conditions and color coding the device to predetermined $h_{FE}$ ranges within the normal $h_{FE}$ limits. A color dot is added to the marking on top of the cap. Any two devices with the same color dot can be paired together to form a matched set of units.

### MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Collector–Emitter Voltage | $V_{CEO}$ | 18 | Vdc |
| Collector–Emitter Voltage | $V_{CES}$ | 36 | Vdc |
| Emitter–Base Voltage | $V_{EBO}$ | 4.0 | Vdc |
| Collector Current — Continuous | $I_C$ | 15 | Adc |
| Total Device Dissipation @ $T_C$ = 25°C<br>Derate above 25°C | $P_D$ | 175<br>1.0 | Watts<br>W/°C |
| Storage Temperature Range | $T_{stg}$ | –65 to +150 | °C |

### THERMAL CHARACTERISTICS

| Characteristic | Symbol | Max | Unit |
|---|---|---|---|
| Thermal Resistance, Junction to Case | $R_{\theta JC}$ | 1.0 | °C/W |

### ELECTRICAL CHARACTERISTICS ($T_C$ = 25°C unless otherwise noted.)

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | |
| Collector–Emitter Breakdown Voltage<br>($I_C$ = 100 mAdc, $I_B$ = 0) | $V_{(BR)CEO}$ | 18 | — | — | Vdc |
| Collector–Emitter Breakdown Voltage<br>($I_C$ = 50 mAdc, $V_{BE}$ = 0) | $V_{(BR)CES}$ | 36 | — | — | Vdc |
| Emitter–Base Breakdown Voltage<br>($I_E$ = 10 mAdc, $I_C$ = 0) | $V_{(BR)EBO}$ | 4.0 | — | — | Vdc |
| **ON CHARACTERISTICS** | | | | | |
| DC Current Gain<br>($I_C$ = 5.0 Adc, $V_{CE}$ = 5.0 Vdc) | $h_{FE}$ | 10 | — | 150 | — |
| **DYNAMIC CHARACTERISTICS** | | | | | |
| Output Capacitance<br>($V_{CB}$ = 12.5 Vdc, $I_E$ = 0, f = 1.0 MHz) | $C_{ob}$ | — | — | 250 | pF |

(continued)