

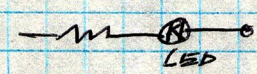
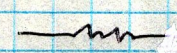
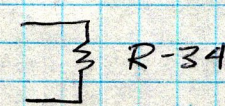
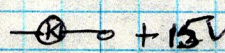
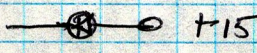
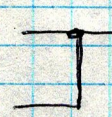



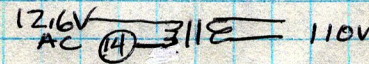


Moral Connector, Cab Control, SWAC 2

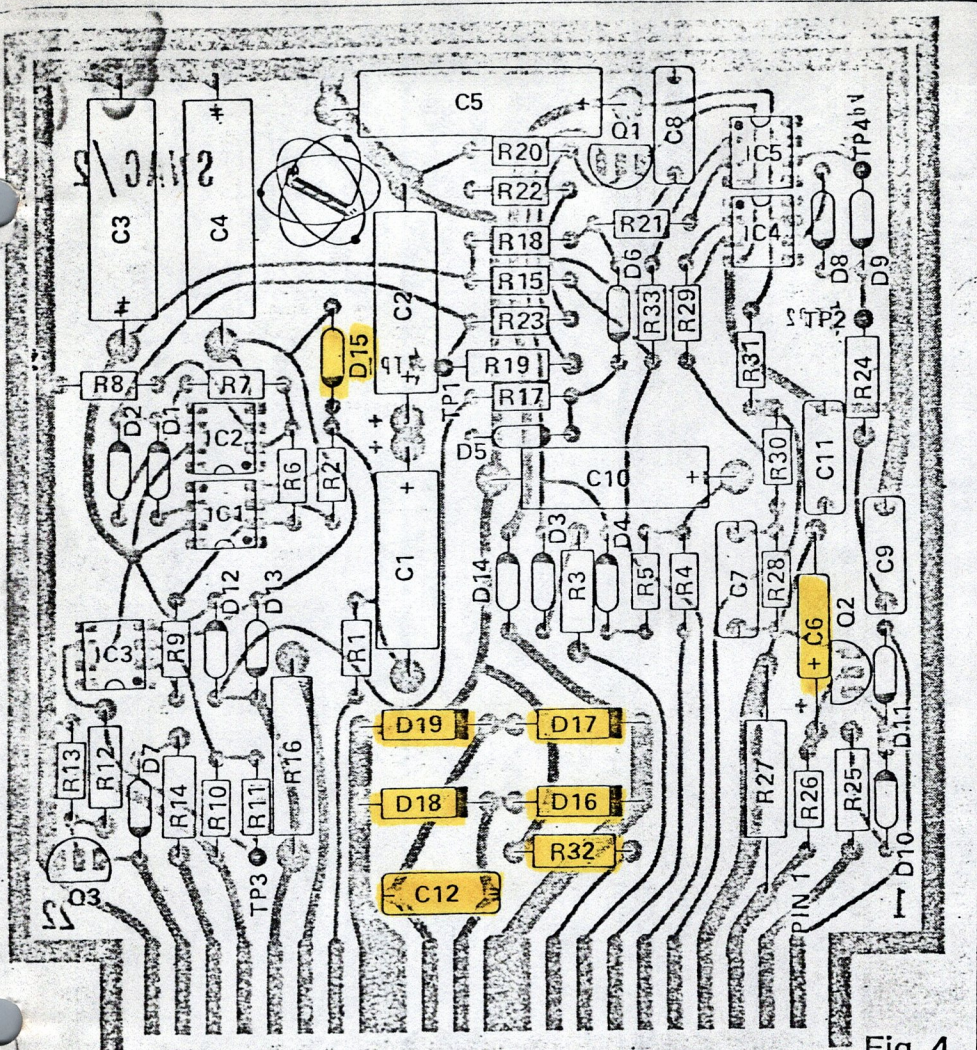
22 EDGE NOVAL

PIN #	Pin #	Color	Function
	1	to pin 4	Switch Machine Supply Ground
	2	N.C.	Voltage sense for meter from pass transistor output when 30V
	3	Brown	Current sense for meter, load side of .15Ω to supply negative
14, 15	4	Black	Main supply negative (-)
1	5	Orange	Input to power amplifier (0 to +16 VDC)
10, 11	6	Red	Main supply positive (+)
3	7	Green	N.C. cover transistor out
4	8	Blue	N.C. power to run relay
21	9	White	Reverse Relay (ground to activate) [+12VDC neg supply]

Connect Pin 1 to Pin 4 to provide return path for relay

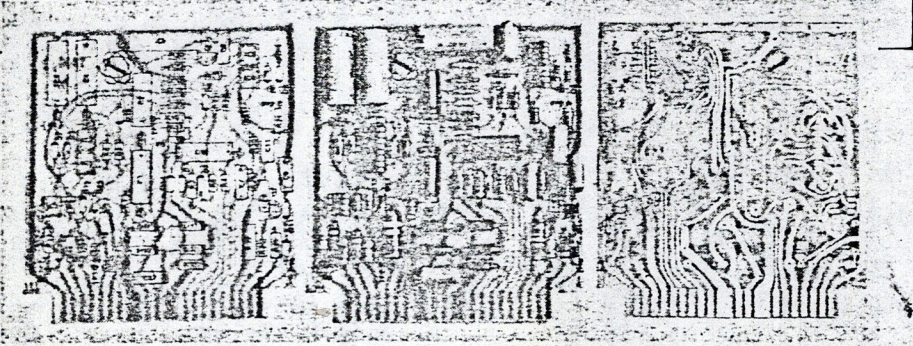
P/C CONN

- 1 Pin 5 OF NOVAL
- 2  +15V (ALARM) OPTIONAL
- 3 + OUT (FROM 2N 3055)
- 4 REV. RELAY (TRACK POWER OUT)
- 5  R-35 CONNECT TO PIN 4
- 6  R-34
- 7
- 8  +15V (GO) OPTIONAL
- 9  +15V (LINE ON) OPTIONAL
- 10  PIN 6 OF NOVAL (+18V)
- 11
- 12 NC
- 13 NC
- 14  PIN 4 OF NOVAL (-18V)
- 15
- 16  TIP CONTROL } (common to 14)
- 17  RING CONTROL }
- 18  12.6V AC (14) 110V
- 19  CONNECT TO 14
- 20 NC
- 21 9 OF NOVAL
- 22  CONNECT TO 14



Component location diagram

Fig. 4



The printed circuit card is shown before (left and right) and after (center) parts have been added.

This type of construction lends itself to a more permanent installation. There are a number of other optional construction details and features you can leave off or add at a later date. The LED's (light-emitting diodes) used as indicators may be left off. The two control pots can be replaced with fixed-value resistors; the optional values listed in the parts list will give satisfactory operation with almost all of the ready-to-run and brass locos. The power on/off switch is not needed if you have a way to remotely turn off the 117 volts feeding the throttle. Things like the SWAT plugs can be eliminated if you wire the units in directly.

The following construction description assumes you are building a single-chassis RAILROAD MODEL CRAFTSMAN

SWAC/2. The test and check-out section assumes that the LED's and meters are installed. These items are used as indicators for most of the tests. Assemble the printed circuit card from information in Fig. 4 and the parts list. When soldering the p.c. card, use a pencil-type soldering iron rated at 20 to 40 watts. Use solder that is marked for use in electronic equipment, as other types of solder can cause damage to the card and components. Keep the tip clean. Heat the part to be soldered with the tip of the iron, then let the part melt the solder (this helps prevent "cold" solder joints). This should take only a second or so, and any additional heating may damage the component. The three-amp diodes will take a little

Op amps

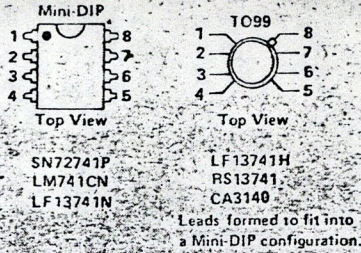


Fig. 5A

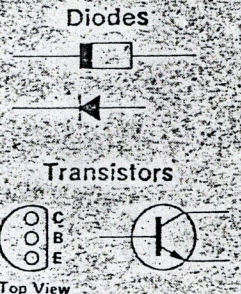


Fig. 5B

DO NOT STUFF FOR CCL
D15-D19, C6, C12, R32
longer to heat than some of the other parts.

When done, check the card for solder splashes and connections you may have skipped. Double check to make sure all parts are in the right location and that diodes and capacitors are placed in the right direction. If you have installed one of the FET op amps for IC1, D15 may be omitted from the p.c. card. Capacitor C6 should only be installed if you intend to operate older O scale equipment with motors that require high current to start.

To lay out the cabinet, position all of the major parts on the inside of the cabinet without drilling any holes. Make a cardboard front panel to fit your cabinet. After deciding how you would like your panel to look, cut out the cardboard panel and fit in the panel parts. Now you can see if the panel will fit without hitting the parts on the inside. If all of the clearances are all right, the inside parts can be mounted.

Here are a few hints for mounting components:

- Large holes for mounting items like the meters can be made with a "nibbling tool" made by Adle Tool Co. You will find these in most electronic supply houses.
- LED's can be mounted using grommets; see the parts list.
- Be sure you leave room to mount the p.c. card connector *with the card in the connector*. Also check to see if the card will short out against any metal parts. If there is a chance of a short, move the card or protect the area so that it can't short.
- Fuses should be mounted so they are easy to get to for replacement. Fuses should not blow out under normal service even with a short on the output.
- The heat sink should be mounted so that air will flow through it.
- Holes in the cabinet for the line cord and wires to the heat sink should be protected with a grommet to prevent the metal from cutting the insulation.

together, so you must be careful not to short the pins. The LED's will not light with the p.c. card removed.

Install the p.c. card with the unit unplugged from the wall outlet. If you plug the card in backwards, you can blow fuse F1. With the card in and power on, the ON LED should turn on and the START and REVERSE LED's may light; the OVERLOAD LED should not light.

Read over the SWAT description, part two of this article, which you should have by this time and build up at least one of these units to complete the check out.

SWAC/2 basic check-out

The following procedure assumes that you are using the two-button or three-button SWAT unit. If you have built one of the other types, you should not have any problems interpreting these instructions.

With SWAC/2 disconnected from the track, connect the SWAT unit and put SWAC/2 into STOP by pushing both the FORWARD and REVERSE buttons (or, for the three-button unit, push the EMERGENCY button). The GO LED should be off. Turn the STOP-SET control to its fully counterclockwise position. The output volt meter should read about 1 to 4 volts. (Once connected to the tracks with any load, this voltage will go to near zero volts.) Turn the control to fully clockwise and the voltage should go to around 6 to 7 volts. Turn the STOP-SET back to the counterclockwise position.

Turn the SLOW-START fully counterclockwise. Push the FORWARD push button until the GO LED just comes up to full on. Turn the SLOW-START to its fully clockwise position. The output meter should come up about 10 volts. Push both buttons or the EMERGENCY and the meter should slowly settle back the 1 to 4 volt reading. The GO LED should be off. Turn the SLOW-START back to the counterclockwise position. Push the REVERSE push button and the REVERSE LED should come on, then the GO LED should come on. With the REVERSE push button held down, the volt meter should come up to around 15 volts. Let go of the push button and the meter should stay at about the same reading. Push the FORWARD button and the volt meter should drop to the 1- to 4-volt reading. The GO LED should turn off. If the FORWARD button is still held down, the REVERSE LED should turn off, the GO LED will come back on and the volt meter should climb back to the 15-volt area.

Push both buttons or the EMERGENCY until the GO LED turns off. Turn the power off. The POWER LED should turn off. Put a short on the output terminals. With pow-

- SWAC/2 parts list
- 1: FRONT PANEL PARTS AND CABINET
Cabinet: equipment box, Calectro H4 74E, Radio Shack 270-281 or a cabinet of your choice.
M1: 0-15 voltmeter (Calectro D1 920, Shurite 8108z or equivalent).
M2: 0-3 ammeter (Calectro D1 918, Shurite 8202z (see note 1), Shurite 8203z which is 0-5 amps, or equivalent).
J1: Three conductor 1/2" phone jack (Radio Shack 274-282 or equivalent; see note 2).
D22, D23: Green LED (light-emitting diode) MV-5222, XC556G or equivalent. See note 3.
D24: Yellow or amber LED, XC522A, XC556Y or equivalent; see note 3.
D25: Red LED, MV5022, XC556R or equivalent; see note 3.
SW1: Single-pole single-throw toggle switch (power on).
R34: 50,000-ohm potentiometer, linear taper (Calectro B1 685, Radio Shack 271-1716, or equivalent; see note 4).
R35: 5,000-ohm potentiometer, linear taper (Calectro B1 680, Radio Shack 271-1714 or equivalent; see note 4).
Knobs: Any knobs that will fit the potentiometer shaft will work. Radio Shack 274-413 is preferred, because they have "calibration" marks from 0 to 10.

2: CHASSIS PARTS

- D20: 3-amp, 50-volt silicon diode (Motorola MR500, Varco V350, Radio Shack 276-1141 or equivalent).
D21: 1-amp, 50-volt silicon diode, 1N4001 (Radio Shack 276-1101 or equivalent).
T1: 16- to 19-volt, 3-amp transformer (Radio Shack 273-1514 or equivalent).
T2: 12- or 12.6-volt, 0.1- to 1-amp transformer (Calectro D1-750, Radio Shack 273-1385 or equiv).
F1: 3-amp fast-acting glass fuse (Radio Shack 270-1276 or equivalent). Use a 3-amp slow blow fuse if capacitor C6 is installed.
F2: 0.250-amp fast-acting glass fuse (Radio Shack 270-1270 or equivalent).
F3: 1-amp fast-acting glass fuse (Radio Shack 270-1273 or equivalent).
Fuse Holders: F1 and F2 use clip-in type like Radio Shack 270-739. For F3 (117 v.a.c.) use an "inline" type like Radio Shack 270-1281.
RY1: D.p.d.t. (double-pole double-throw) 12-volt relay (Radio Shack 275-206; see note 5).
R36: 100-ohm 0.5-watt resistor (see note 5).
Q4: 2N6576 power Darlington transistor.
Heat sink: Motorola MS-10, Radio Shack 276-1361, Calectro J4-880 or equivalent.
Transistor mounting kit: Motorola MK-15, Radio Shack 276-1371 or equivalent. Use with silicon grease like Radio Shack 276-1372.

PARTS LIST NOTES:

- 1: Shurite has discontinued the 0-3 amp meter in the 850 series. This meter is still available from Shurite by special order.
2: Insulate jack J1 from the frame ground with nonconductive washers. Fiber or nylon shoulder washers like H.H. Smith 2158 are designed for this application. Without insulation, the circuit ground connected to the sleeve of the jack can short to frame ground. Another way to insulate this jack is to mount it on a wood or plastic panel.
3: Almost any of the red, yellow, or green LED's will work in this circuit. The colors listed are what we used. You can change them around to suit yourself or use all of one color if you like. Radio Shack sells a package of assorted LED's that should yield a sufficient number of devices for this application. Here's a suggestion for mounting the LED's to your panel: Use a small rubber grommet to hold the LED and drill the panel to fit the grommet. A 3/16" inside diameter grommet works out to about the right size for most 0.185" to 0.200" o.d. LED's.
4: Both of the potentiometers may be replaced with fixed-value resistors. For R34, try a 33,000-ohm resistor; for R35, try a 3,300-ohm resistor. Values can be changed if you desire. In both cases, the higher the value the lower the voltage output.
5: Any 12-volt d.c. relay may be used as long as the coil resistance is more than about 90 ohms and the contacts are rated for more than 3 amps. Resistor R36 allows a 12-volt relay to work with the 16 to 19 volts + Vp. The value of R36 should be about half the value of the relay coil resistance. If you were to use the Radio Shack heavy-duty 10-amp, 12-volt relay 276-208, which has a coil resistance of 95 ohms, the value of R36 would be about 50 ohms (47 ohms would be the standard value near 50 ohms). One more note on this resistor: If the value required is less than 75 ohms, use a one watt resistor; if the value is over 75 ohms, a half-watt will work.
You can also try a 24-volt d.c. coil relay. Most of the 24-volt relays will operate on 16 to 18 volts. If you do use a 24-volt relay, it should have a coil resistance of more than 140 ohms. With a 24 volt coil, you can omit resistor R36.
6: The following items for SWAC/2 are available from the author through Gold Spike Lab., P.O. Box 24772, San Jose, CA 95154. All items are postpaid (for U.S.A. shipments). California residents please add 6.5% sales tax.
SWAC/2 p.c. card: Mil-spec glass epoxy board, drilled, reflow soldered, gold-plated contact fingers, and silk screened with the parts location information (see Fig. 4); \$10.00.
SWAC/2 parts kit: Includes the p.c. card, connector, all of the parts that mount on the p.c. card except optional capacitor C6 (all other caps, resistors, diodes, FET op amp, op amps, and transistors) plus the off-card diodes (D20 and D21, but not the LED's), output transistor (Q4) and the two insulating washer for the SWAT jack (J1); \$40.00.

If you cannot obtain other parts from local sources, send a large SSAE to Gold Spike Lab. for a list of parts available through them.

DO NOT STUFF FOR CCL

SWAC voltage check-out chart

Pin	Line name	STOP*	FWD*	REV*
1:	Drive to Q4 base	3.0	18	16
2:	To overload LED (note A)	-0.1	-0.1	-0.1
3:	From Q4 emitter	3.1	17.5	15
4:	To output	3.1	17.5	15
5:	To stop-set pot	8.2	10	9.7
6:	To slow-start pot	18	4.7	4.5
7:	From slow-start pot	18	4.7	4.5
8:	To go LED (note A)	-0.1	-2	-2
9:	To on LED (note A)	-2	-2	-2
10 & 11:	+Vp output	17.5	18.5	17
12 & 13:	Input 16-19 v.a.c. (note B)	20v.a.c.	20v.a.c.	20v.a.c.
14 & 15:	Circuit ground	0	0	0

16:	Control lead from SWAT	0	17	-16
17:	Output 12v.a.c. to SWAT	14v.a.c.	14v.a.c.	14v.a.c.
18:	From 12v.a.c. transformer	14v.a.c.	14v.a.c.	14v.a.c.
19:	Circuit ground	0	0	0
20:	To reverse LED (note A)		-0.1	-2
21:	To reverse relay coil		17.5	0
22:	Circuit ground	0	0	0
Card test points				
TP1:	IC1 & IC2 output	0.6	15	15
TP2:	IC4 & IC5 output	3.0	24	22.6
TP3:	IC3 output		-15	15
TP4:	IC5 output	1.8	17.5	15
**"STOP" measurement taken with emergency button pushed on SWAT unit.				
**"FWD" measurement taken with forward button held down on SWAT unit.				

- Connector for printed circuit card: 22 pin, 0.151-inch centers (Cinch 50-22A-20, Amphenol 143-022-01, Dale E370-A2ZGF or equivalent).
Miscellaneous: Line cord, decals, mounting hardware, and so on.
Connector, binding posts: Radio Shack 274-661 (two in a package; four required), or equivalent.
3: PRINTED CIRCUIT CARD
C1, C2, C10: 100uf, 25-volt miniature aluminum electrolyte capacitor.
C3, C4, C5: 220uf or 250uf, 25-volt miniature aluminum electrolyte capacitor.
C6: 33uf or 47uf, 10-volt miniature aluminum electrolyte capacitor; install only if SWAC/2 is to be used with older O scale equipment.
C7: 0.01uf, 100-volt, ±10% polyester film capacitor (Sprague type 225P-10391WD, Radio Shack 272-1065 or equivalent).
C8, C9, C11, C12: 0.1uf, 100-volt, ±10% polyester film capacitor (Sprague type 225P-10491WD, Radio Shack 272-1069, or equivalent).
D1 to D14: 1-amp, 50-volt silicon diode, 1N4001 or equivalent.
D15: 10-milliamp, 75-volt silicon diode, 1N4148 or equivalent (this diode is only needed when a standard 741 op amp, like IC2 to IC5, is used for IC1).
D16 to D19: 3-amp, 50-volt silicon diode (Motorola MR500, Varco 350V, Radio Shack 276-1141 or equivalent).
IC1: FET input op amp. (National LF13741N, Radio Shack RS13741 their number 276-1733, CA3140 (D15 not needed with these) or the standard bipolar 741 as listed for IC2 to IC5. The FET op amp is preferred for minimum drift of capacitors C1 and C2. See Fig. 5).
IC2 to IC5: Op amp, 741 type in an 8-pin mini-DIP package (National LM741CN, Signetics uA741CV, TI SN72741P or equivalent).
Q1, Q2, Q3: 2N3904, MPS3904, MPS2923 or equivalent.
All resistors 1/2-watt, 10% unless otherwise noted.
R1: 3,300-ohms.
R2, R15: 33,000-ohms.
R3, R12, R14, R19, R24, R25, R32: 1000-ohms, 1/2 watt, 10%.
R4, R8, R9, R11, R17, R21, R28, R29, R30, R31, R33: 10,000-ohms.
R5: 1000-ohms, 1/2-watt, 10%.
R6, R7, R23: 18,000-ohms, 1/4-watt, 5%.
R10, R13, R26: 470-ohms.
R16: 100-ohms, 2-watts, 10%.
R18: 68,000 ohms, 1/2-watt, 5%.
R20: 2,400 ohms, 1/2-watt, 5%.
R22: 120,000 ohms.
R27, R28: 2-watts, 5%, wire wound.
Printed-circuit card: Make from artwork or purchase from Gold Spike Lab.; see note 6.

**"REV" measurement taken with reverse button held down on SWAT unit.
No measurements are given for pins 20, 21 and TP3 in the STOP column because the output can be either forward or reverse at STOP.
Measurement information
These measurements were taken on a SWAC/2 with a 18.9 v.a.c. transformer T1 (12.6v.a.c. plus 6.3v.a.c.) and a 12.6v.a.c., 0.1 amp transformer T2. The pots should be set with the slow-start turned fully clockwise (full on) and the stop set turned fully counterclockwise (minimum output). Use a meter with a 20,000 ohms-per-volt or better rating.
Note A: Measure with the volt-meter-plus lead connected to +Vp (pin 10 or 11).
Note B: Measure with volt meter connected to pins 12 and 13; remember that this is an "a.c." reading!
All other measurement taken with the "other" lead connected to circuit ground. Variations of ±10% are normal.

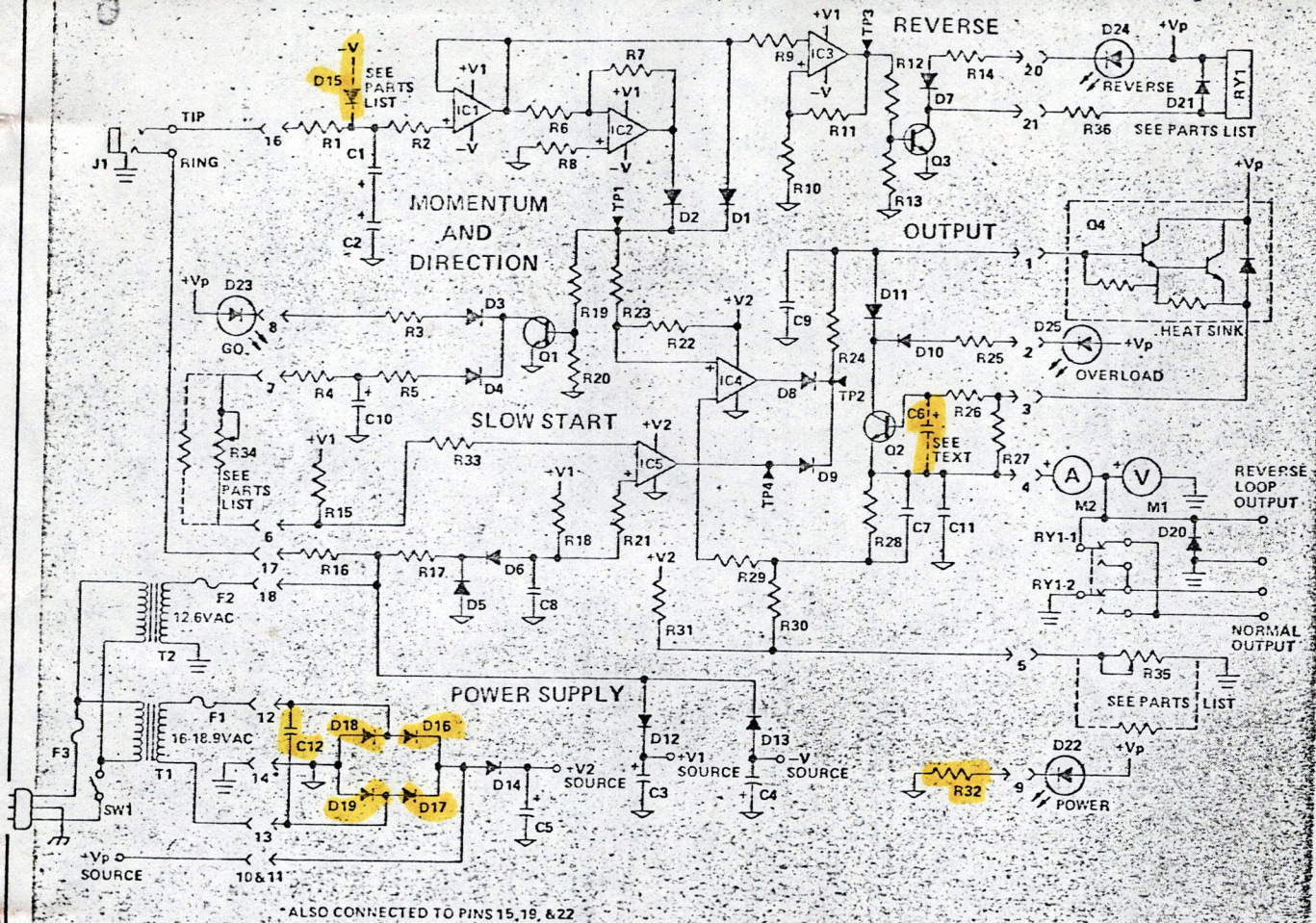


Fig. 1

Schematic wiring diagram

DO NOT STUFF FOR CCL → D15-D19, C6, C12, R32

GRAPHICS/FRANK GERACI

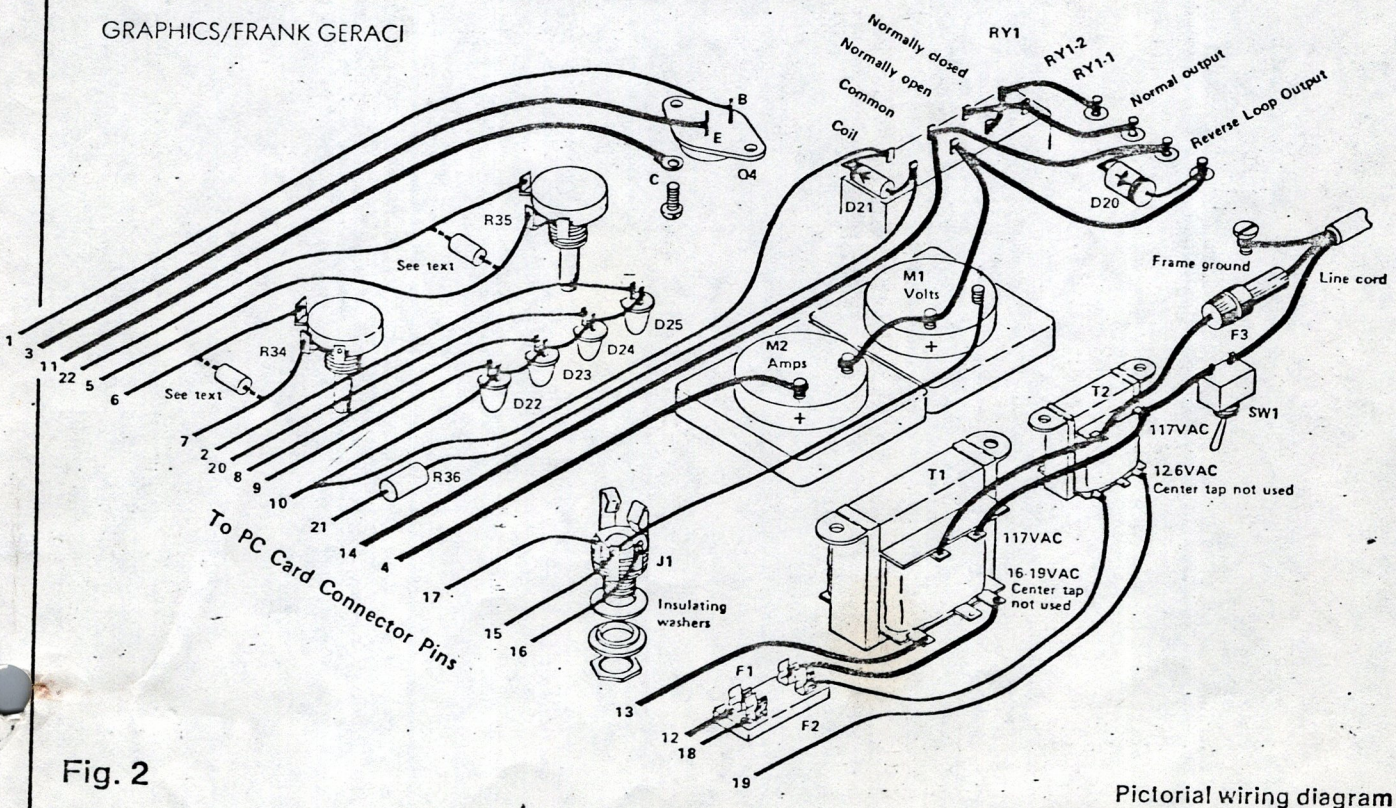


Fig. 2

Pictorial wiring diagram

together, so you must be careful not to short the pins. The LED's will not light with the p.c. card removed.

Install the p.c. card with the unit unplugged from the wall outlet. If you plug the card in backwards, you can blow fuse. With the card in and power on, the ON LED should turn on and the START and REVERSE LED's may light; the OVERLOAD LED should not light.

Read over the SWAT description, part two of this article, which you should have by this time and build up at least one of these units to complete the check out.

SWAC/2 basic check-out

The following procedure assumes that you are using the two-button or three-button SWAT unit. If you have built one of the other types, you should not have any problems interpreting these instructions.

With SWAC/2 disconnected from the track, connect the SWAT unit and put SWAC/2 into STOP by pushing both the FORWARD and REVERSE buttons (or, for the three-button unit, push the EMERGENCY button). The GO LED should be off. Turn the STOP-SET control to its fully counterclockwise position. The output volt meter should read about 1 to 4 volts. (Once connected to the tracks with any load, this voltage will go to near zero volts.) Turn the control to fully clockwise and the voltage should go to around 6 to 7 volts. Turn the STOP-SET back to the counterclockwise position.

Turn the SLOW-START fully counterclockwise. Push the FORWARD push button until the GO LED just comes up to full position. The output meter should come up about 10 volts. Push both buttons or the EMERGENCY and the meter should slowly settle back the 1 to 4 volt reading. The GO LED should be off. Turn the SLOW-START back to the counterclockwise position. Push the REVERSE push button and the REVERSE LED should come on, then the GO LED should come on. With the REVERSE push button held down, the volt meter should come up to around 15 volts. Let go of the push button and the meter should stay at about the same reading. Push the FORWARD button and the volt meter should drop to the 1- to 4-volt reading. The GO LED should turn off. If the FORWARD button is still held down, the REVERSE LED should turn off, the GO LED will come back on and the volt meter should climb back to the 15-volt area.

Push both buttons or the EMERGENCY until the GO LED turns off. Turn the power off. The POWER LED should turn off. Put a short on the output terminals. With pow-

SWAC/2 parts list

1: FRONT PANEL PARTS AND CABINET

- Cabinet-equipment box: Calectro H4-748, Radio Shack 270-281 or a cabinet of your choice.
 M1: 0-15 voltmeter (Calectro D1-920, Shurite 8108z or equivalent).
 M2: 0-3 ammeter (Calectro D1-918, Shurite 8202z (see note 1), Shurite 8203z which is 0-5 amps, or equivalent).
 J1: Three conductor 1/4" phone jack (Radio Shack 274-282 or equivalent; see note 2).
 D22, D23: Green LED (light-emitting diode) MV-5222, XC556G or equivalent. See note 3.
 D24: Yellow or amber LED, XC522A, XC556Y or equivalent; see note 3.
 D25: Red LED, MV5022, XC556R or equivalent; see note 3.
 SW1: Single-pole single-throw toggle switch (power on).
 R34: 50,000-ohm potentiometer, linear taper (Calectro B1 685, Radio Shack 271-1716, or equivalent; see note 4).
 R35: 5,000-ohm potentiometer, linear taper (Calectro B1 680, Radio Shack 271-1714 or equivalent; see note 4).
 Knobs: Any knobs that will fit the potentiometer shaft will work. Radio Shack 274-413 is preferred, because they have "calibration" marks from 0 to 10.

2: CHASSIS PARTS

- D20: 3-amp, 50-volt silicon diode (Motorola MR500, Varco V350, Radio Shack 276-1141 or equivalent).
 D21: 1-amp, 50-volt silicon diode, 1N4001 (Radio Shack 276-1101 or equivalent).
 T1: 16- to 19-volt, 3-amp transformer (Radio Shack 273-1514 or equivalent).
 T2: 12- or 12.6-volt, 0.1- to 1-amp transformer (Calectro D1-750, Radio Shack 273-1385 or equiv).
 F1: 3-amp fast-acting glass fuse (Radio Shack 270-1276 or equivalent). Use a 3-amp slow blow fuse if capacitor C6 is installed.
 F2: 0.250-amp fast-acting glass fuse (Radio Shack 270-1270 or equivalent).
 F3: 1-amp fast-acting glass fuse (Radio Shack 270-1273 or equivalent).
 Fuse Holders: F1 and F2 use clip-in type like Radio Shack 270-739. For F3 (117 v.a.c.) use an "in-line" type like Radio Shack 270-1281.
 RY1: D.p.d.t. (double-pole double-throw) 12-volt relay (Radio Shack 275-206; see note 5).
 R36: 100-ohm 0.5-watt resistor (see note 5).
 Q4: 2N6576 power Darlington transistor.
 Heat sink: Motorola MS-10, Radio Shack 276-1361, Calectro J4-880 or equivalent.
 Transistor mounting kit: Motorola MK-15, Radio Shack 276-1371 or equivalent. Use with silicon grease like Radio Shack 276-1372.

PARTS LIST NOTES:

- 1: Shurite has discontinued the 0-3 amp meter in the 850 series. This meter is still available from Shurite by special order.
 2: Insulate jack J1 from the frame ground with nonconductive washers. Fiber or nylon shoulder washers like H.H. Smith 2158 are designed for this application. Without insulation, the circuit ground connected to the sleeve of the jack can short to frame ground. Another way to insulate this jack is to mount it on a wood or plastic panel.
 3: Almost any of the red, yellow, or green LED's will work in this circuit. The colors listed are what we used. You can change them around to suit yourself or use all of one color if you like. Radio Shack sells a package of assorted LED's that should yield a sufficient number of devices for this application. Here's a suggestion for mounting the LED's to your panel: Use a small rubber grommet to hold the LED and drill the panel to fit the grommet. A 1/16" inside diameter grommet works out to about the right size for most 0.185" to 0.200" o.d. LED's.
 4: Both of the potentiometers may be replaced with fixed-value resistors. For R34, try a 33,000-ohm resistor; for R35, try a 3,300-ohm resistor. Values can be changed if you desire. In both cases, the higher the value the lower the voltage output.
 5: Any 12-volt d.c. relay may be used as long as the coil resistance is more than about 90 ohms and the contacts are rated for more than 3 amps. Resistor R36 allows a 12-volt relay to work with the 16 to 19 volts + Vp. The value of R36 should be about half the value of the relay coil resistance. If you were to use the Radio Shack heavy-duty 10-amp, 12-volt relay 276-208, which has a coil resistance of 95 ohms, the value of R36 would be about 50 ohms (47 ohms would be the standard value near 50 ohms). One more note on this resistor. If the value required is less than 75 ohms, use a one watt resistor; if the value is over 75 ohms, a half-watt will work. You can also try a 24-volt d.c. coil relay. Most of the 24-volt relays will operate on 16 to 18 volts. If you do use a 24-volt relay, it should have a coil resistance of more than 140 ohms. With a 24 volt coil, you can omit resistor R36.
 6: The following items for SWAC/2 are available from the author through Gold Spike Lab., P.O. Box 24772, San Jose, CA 95154. All items are postpaid (for U.S.A. shipments). California residents please add 6.5% sales tax. SWAC/2 p.c. card: Mil-spec glass epoxy board, drilled, reflow soldered, gold-plated contact fingers, and silk screened with the parts location information (see Fig. 4); \$10.00.
 SWAC/2 parts kit: Includes the p.c. card, connector, all of the parts that mount on the p.c. card except optional capacitor C6 (all other caps, resistors, diodes, FET op amp, op amps, and transistors) plus the off-card diodes (D20 and D21, but not the LED's), output transistor (Q4) and the two insulating washer for the SWAT jack (J1); \$40.00.
 If you cannot obtain other parts from local sources, send a large SSAE to Gold Spike Lab. for a list of parts available through them.

Connector for printed circuit card: 22 pin on 0.156-inch centers (Cinch 50-22A-20, Amphenol 143-022-01, Dale E370-A226F or equivalent).

Miscellaneous: Line cord, decals, mounting hardware, and so on.

Connector, binding posts: Radio Shack 274-661 (two in a package; four required), or equivalent.

3: PRINTED CIRCUIT CARD

- C1, C2, C10: 100uf, 25-volt miniature aluminum electrolyte capacitor.
 C3, C4, C5: 220uf or 250uf, 25-volt miniature aluminum electrolyte capacitor.
 C6: 33uf or 47uf, 10-volt miniature aluminum electrolyte capacitor; install only if SWAC/2 is to be used with older O scale SWAT.
 C7: 0.01uf, 100-volt, ±10% polyester film capacitor (Sprague type 225P-10391WD, Radio Shack 272-1065 or equivalent).
 C8, C9, C11, C12: 0.1uf, 100-volt, ±10% polyester film capacitor (Sprague type 225P-10491WD, Radio Shack 272-1069, or equivalent).
 D1 to D14: 1-amp, 50-volt silicon diode, 1N4001 or equivalent.
 D15: 10-milliamp, 75-volt silicon diode, 1N4148 or equivalent (this diode is only needed when a standard 741 op amp, like IC2 to IC5, is used for IC1).
 D16 to D19: 3-amp, 50-volt silicon diode (Motorola MR500, Varco 350V, Radio Shack 276-1141 or equivalent).
 IC1: FET input op amp. (National LF13741N, Radio Shack RS13741 their number 276-1733, CA3140 (D15 not needed with these) or the standard bipolar 741 as listed for IC2 to IC5. The FET op amp is preferred for minimum drift of capacitors C1 and C2. See Fig. 5).

IC2 to IC5: Op amp, 741 type in an 8-pin mini-DIP package (National LM741CN, Signetics uA741CV, TI SN74741P or equivalent).

Q1, Q2, Q3: 2N3904, MPS3904, MPS2923 or equiv.

All resistors 1/4-watt, 10% unless otherwise noted.

R1: 3,300-ohms.

R2, R15: 33,000-ohms.

R3, R12, R14, R19, R24, R25, R32: 1000-ohms, 1/2 watt, 10%.

R4, R8, R9, R11, R17, R21, R28, R29, R30, R31, R33: 10,000-ohms.

R5: 1000-ohms, 1/4-watt, 10%.

R6, R7, R23: 18,000-ohms, 1/4-watt, 5%.

R10, R13, R26: 470-ohms.

R16: 100-ohms, 2-watts, 10%.

R18: 68,000 ohms, 1/4-watt, 5%.

R20: 2,400 ohms, 1/4-watt, 5%.

R22: 120,000 ohms.

R27: 0.27-ohms, 2-watts, 5%, wire wound.

Printed-circuit card: Make from artwork or purchase from Gold Spike Lab.; see note 6.

SWAC voltage check-out chart

Pin	Line name	STOP*	FWD*	REV*
1:	Drive to Q4 base	3.0	18	16
2:	To overload LED (note A)	-0.1	-0.1	-0.1
3:	From Q4 emitter	3.1	17.5	15
4:	To output	3.1	17.5	15
5:	To stop-set pot	8.2	10	9.7
6:	To slow-start pot	18	4.7	4.5
7:	From slow-start pot	18	4.7	4.5
8:	To go LED (note A)	-0.1	-2	-2
9:	To on LED (note A)	-2	-2	-2
10 & 11:	+Vp output	17.5	18.5	17
12 & 13:	Input 16-19 v.a.c. (note B)	20v.a.c.	20v.a.c.	20v.a.c.
14 & 15:	Circuit ground	0	0	0

16:	Control lead from SWAT	0	17	-16
17:	Output 12v.a.c. to SWAT	14v.a.c.	14v.a.c.	14v.a.c.
18:	From 12v.a.c. transformer	14v.a.c.	14v.a.c.	14v.a.c.
19:	Circuit ground	0	0	0
20:	To reverse LED (note A)	-0.1	-2	-2
21:	To reverse relay coil	17.5	0	0
22:	Circuit ground	0	0	0
Card test points				
TP1:	IC1 & IC2 output	0.6	15	15
TP2:	IC4 & IC5 output	3.0	24	22.6
TP3:	IC3 output	-15	15	15
TP4:	IC5 output	1.8	17.5	15
**"STOP" measurement taken with emergency button pushed on SWAT unit.				
**"FWD" measurement taken with forward button held down on SWAT unit.				

**"REV" measurement taken with reverse button held down on SWAT unit.

No measurements are given for pins 20, 21 and TP3 in the STOP column because the output can be either forward or reverse at STOP.

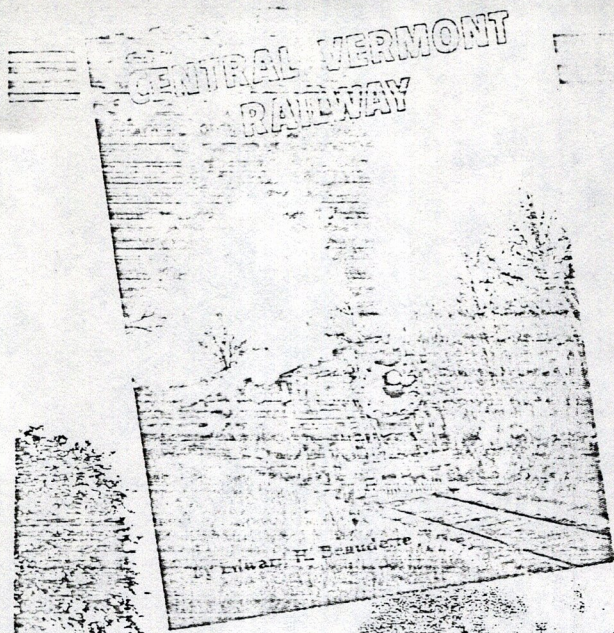
Measurement information

These measurements were taken on a SWAC/2 with a 18.9 v.a.c. transformer T1 (12.6v.a.c. plus 6.3v.a.c.) and a 12.6v.a.c., 0.1 amp transformer T2. The pots should be set with the slow-start turned fully clockwise (full on) and the stop set turned fully counterclockwise (minimum output). Use a meter with a 20,000 ohms-per-volt or better rating.

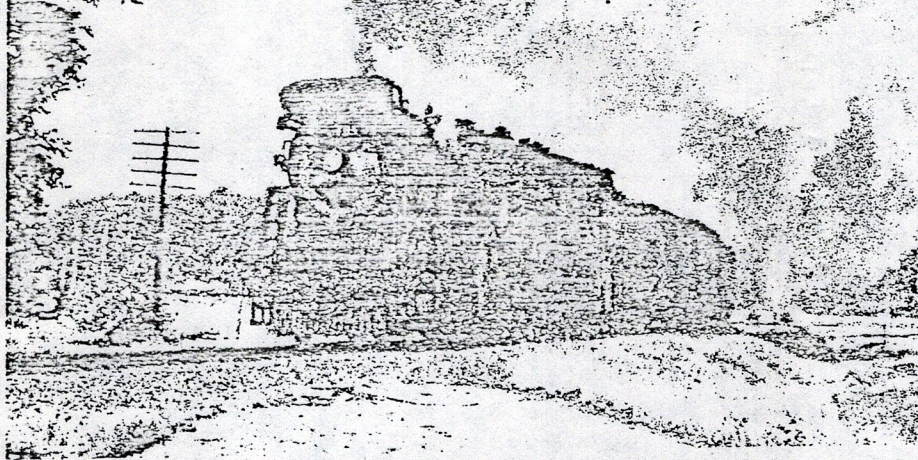
Note A: Measure with the volt-meter-plus lead connected to +Vp (pin 10 or 11).

Note B: Measure with volt meter connected to pins 12 and 13; remember that this is an "a.c." reading!

All other measurement taken with the "other" lead connected to circuit ground. Variations of ±10% are normal.



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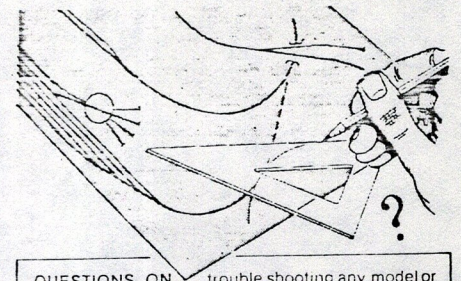
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Steel loads gons

Q Two things caught my eye in Todd Sullivan's article on steel loads (July, 1982, RMC). First, what scale are the models, and secondly, I have never seen models of either the RBOX boxcar or the PC gondola in the photos. Can you identify them?

A Sure can. The scale is HO. The PC gondola is a kit available from National Car Cast, 134 Allen St. East, Waterloo, Ontario N2J 1H9, Canada. Write for current prices and availability, including an addressed envelope for reply. The Railbox boxcar is a modified Athearn kit—TODD SULLIVAN.

Modern HO_{n3} diesels

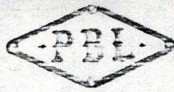
Q Has anyone ever made any models of modern HO_{n3} motive power?

A Iron Horse Models produced a White Pass & Yukon DL535E diesel in 1979; you may be able to pick one up at a swap session, through the used locomotive listings in ads or via a notice in EXCHANGE PLACE.

SWAC/2 transistor replacement

Q I'm currently building a SWAC/2 throttle as described in the August/September, 1977, RMC. My problem is that the output transistor Q4, a 2N6576, is not available in Australia. Could you suggest a possible alternative source for this transistor?

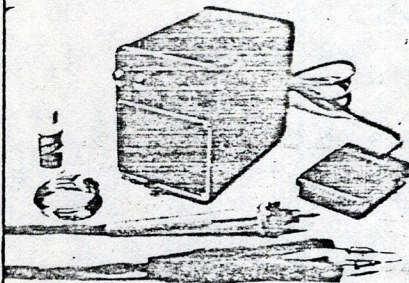
A The specs of the 2N6576 are as follows: it is a power Darlington transistor mounted in a TO-3 case. It has a rating of 115 watts @ 25 C, 60 volts maximum, and maximum collector current of 15 amps. Because it is a Darlington, the gain is a minimum of 10,000. There are a number of these now available. These specs should be sufficient to find a suitable substitute. Radio Shack transistor RS2041 (No. 276-2041) meets these—DON FIEHMANN.



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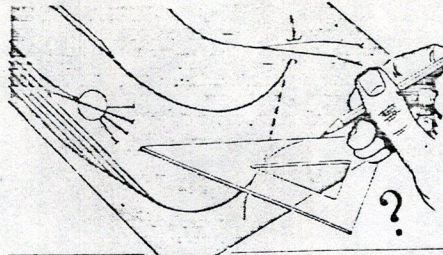
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SWAC/2 article corrections and additions

Q I would like to build the SWAC/2 throttle as shown in the August and September 1977 RMC articles. Have there been any corrections or additions to the article since it was printed?

A There have not been any corrections printed since the article was published. To my knowledge, there are no errors in the article as it stands. The only additions have been the R/C SWAT article in the September

1980 RMC and the SWA16 article in the March 1982 RMC—DON FIEHMANN.

Lehigh & New England FA1's

Q I am currently modeling several of the L&NE's Alco FA1's, as described in the November 1981 RMC. I find that the large white stripes which go around the bottom of the body and the thin white stripe just below the grilles are not included in the Walthers decal set mentioned in the article. What size striping decals would be appropriate to use?

A It's been quite a while since I built my L&NE FA1's, but, as I recall, there was a separate sheet of 9" wide white decal stripes included in the Walthers No. 67-90 package. Since I plan to do two more units myself, I recently ordered new sets and have noticed, as you mentioned, that this striping was missing. It would seem as though the initial sets I used were from an earlier run in which the stripes were included and that the current sets do indeed lack the extra sheet of stripes. Prototypically, the stripes under the grilles are 3" wide and the stripe running around the bottom of the carbody is 9" wide. My approach to modeling subsequent L&NE FA's will be to paint the shells white and, when dry, mask off the stripes before applying the black. This will insure that the stripes are suitably opaque and it will provide an easier approach to achieving the 3" stripe which, in decal form, was difficult to apply over the rivets under the FA grilles.—WAYNE SITTNER.

Stripping paint from plastic engines

Q I Model in N scale and would like to repaint and reletter some of my motive

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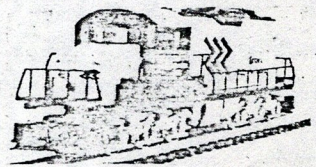
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SWAT 1-5

PHOTOGRAPHY: THE AUTHOR

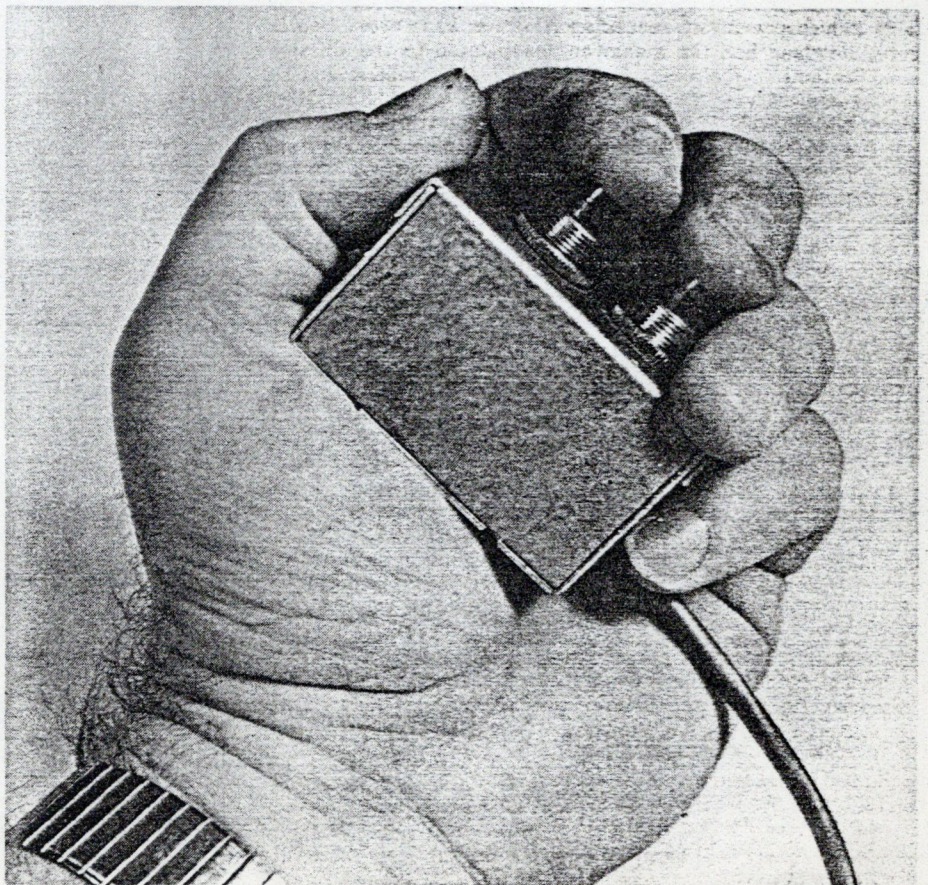
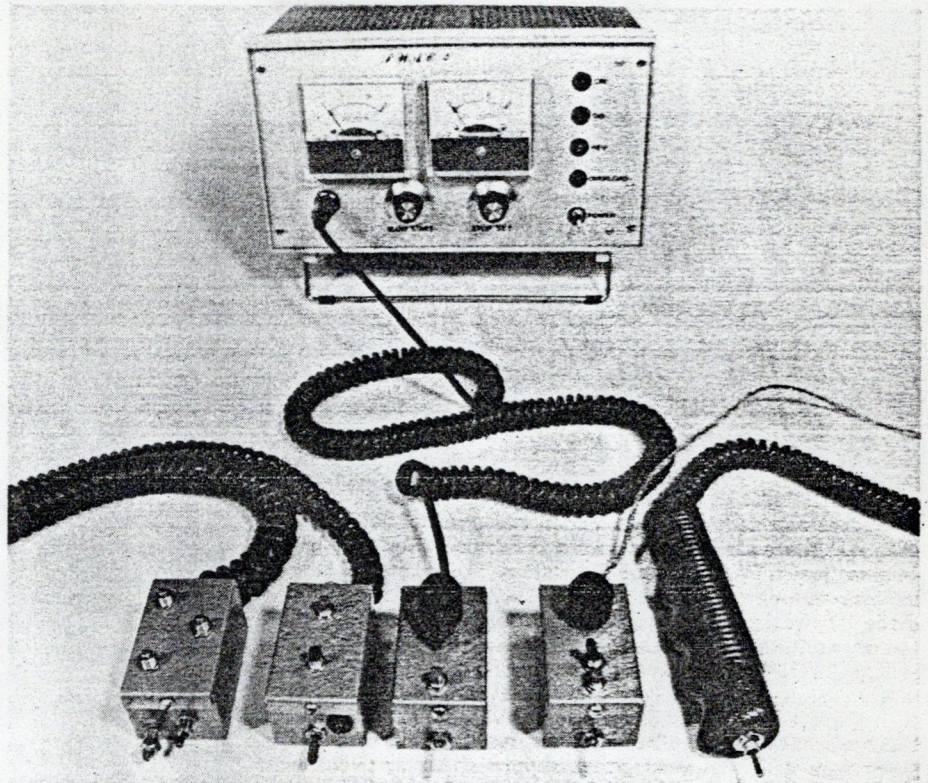
Part 2: With the SWAC/2 power supply completed, there are an almost limitless variety of walk-around throttles which can be built to use with it, five of which are described here/Don Fiehmnn

The first part of this article dealt with the controller of this new type of walk-around throttle system. This system requires two units to operate: the controller (SWAC), and a hand-held throttle (SWAT). This part of the article deals with the operation and construction of a number of different types of hand-held throttles. All of these SWAT's are interchangeable and will plug into SWAC/2 without any changes. The choice of which unit(s) to build depends on your own tastes, applications or operation. If none of these suit you, design your own, as a number of SWAC/2 users have already done. The limit is your own imagination. For example, if you mounted two push-button switches in a pair of shoes so that the buttons could be operated with your toes, you could build a hands-free throttle!

When this series of hand-held throttles was first developed, a number of rules were established in order to have each of the SWAT's controls work in a similar fashion. To review, the rules for the speed controls are: FORWARD is up or right, REVERSE is down or left. The rule for the acceleration switch, if one is installed, is front for "fast" and back for "slow." These rules make it a lot easier to remember when switching from one SWAT to another. It's also a bit easier for guest engineers to master quickly.

Basic SWAT circuits

There are some fundamentals that all SWAT's use to signal speed and direction to the SWAC/2. All control information is sent over the single wire (tip lead) that connects to the momentum capacitor (C1 and C2) through resistor R1 in SWAC/2. Circuit ground or near zero volts is STOP, "plus" is FORWARD and "minus" is REVERSE. The greater the charge (voltage), the faster the speed. All SWAT's use the 12-volt a.c. lead (ring) to develop the plus and minus voltage to feed back to SWAC/2. The third lead (sleeve) is circuit ground and is used for a number of functions. Connecting the control lead to ground will cause an emergency stop. A resistor, diode and LED can be connected between the 12



wires and ground for a power on-and-connected indicator in the SWAT unit.

General construction

All SWAT units in this article (except type 5) were built into the smallest size metal box that I could find. This is the LBM box M00 which measures 2.25x1.5x1.375 inches.

Three-wire stereo headphone cords are used to connect SWAT to SWAC/2. There are a number of different ways these can be used. You can buy a stereo headphone replacement cord like Radio Shack 42-2476 and solder it directly into the SWAT circuits. Another way is to connect a short (say, six-inch) piece of three-wire flexible cord to the SWAT circuits and then connect a three-wire phone plug like Radio Shack 274-139 to the other end. This way you can plug the SWAT into a stereo headphone extension cord like Radio Shack 42-2442 or 42-2443. Since these are standard parts, you should be able to buy the cords and plugs from almost any of the hi-fi and stereo shops. One nice thing about using the stereo headphone extension cords is that they will still work for the headphones when not in use on the railroad.

One of the local stereo shops had a sale on stereo headphone extension cords for \$2.50 each. I bought a couple of them at this price, and the salesman tried to sell me a set of "super-duper" headphones to go with the cords. He got the strangest look on his face when I told him what the cords were going to be used for. I have plugged six of the 25-foot cords together for a total of 150 feet and found that they worked just as well as a short cord on both the SWAC/2-SWAT and the headphones. I don't advise trying to cross-connect your headphones to a SWAC/2, however.

An acceleration control for momentum can be added to any of these units. This control can be either a potentiometer (pot) or switch, or you can put in a fixed value. Any R1X0 (R110, R120, R130, . . .) can be installed to suit yourself; see Fig. 11. The pot should be 250,000 ohms. If you use a small pot with a screw adjustment, it can be mounted inside the SWAT, and a small hole can be used for access to the adjustment—or use a standard pot with a knob on the outside. If you use a switch, get one of the single-pole double-throw miniature toggle switches. (Remember, room is at a premium inside the small box.) The resistor values that I like best in the toggle switch arrangement are 18,000 ohms for a "yard" rate and 180,000 ohms for a "main-line" rate. If you use only one resistor, try 33,000 ohms. Remember, if it's too slow for you, lower the value; if it's too fast, increase the value.

An EMERGENCY push button can also be added to any of the SWAT's or even to the front panel of the SWAC/2 by wiring the normally-open contact of the switch to the control lead and the common contact to the

Making p.c. cards from Fig. 3

If you are using the artwork in Fig. 3 (part one) to make your own SWAC/2 printed-circuit card, be sure that the image on your film is the correct size before you etch the card. There are a number of factors that can affect the size of the artwork in the magazine despite efforts to print it correctly, such as paper expansion in humid conditions. To check for the correct size on your finished film, use the spacing of the contact fingers (0.156 inches) or the spacing of the holes for the IC's (0.100 inches) as a reference. Measure across as many as possible to minimize the reading error; for example, the 0.156-inch spacing times 21 fingers equals 3.276 inches—DON FIEHMANN.

circuit ground. Operation of the push button shorts these two leads together for an emergency stop. R1 on the SWAC/2 p.c. card limits the speed of the emergency stop to "fast but not too fast." (If you would like to use only two wires with SWAT/1, 2 or 5, you can wire the emergency button between the 12-volt a.c. lead and the control lead. This will work almost as well as the circuit ground, because the 12 volts a.c. is plus for the same length of time as it is minus, and the average of the two is zero volts. The momentum capacitor will charge to the average due to resistor R1 in series with C1 and C2.)

If you are using the small LMB metal box, check the box to be sure that both halves will fit together if you have mounted parts in each. If in doubt, build a model out of cardboard.

Be sure to use a rubber grommet where the cable comes into the box to prevent the metal from cutting the wires. Also provide strain relief for the cable wires. I normally tie a knot in the cable so that it will not pull out if there is strain on the cable. One of the nice things about using a short piece of cable on the SWAT is that when you step on the extension cord and then move, SWAT disconnects at the two phone connectors.

SWAT/1: three-button control

This SWAT unit uses single-pole push-button switches with the top button for FORWARD, bottom button for REVERSE and the middle button for EMERGENCY. The optional ACCELERATION switch can be added to this SWAT if you desire. This unit can be operated with one hand very easily. Pushing the FORWARD and REVERSE buttons at the same time will cause the output voltage of the SWAC/2 to go to stop quickly, but not as fast as with the EMERGENCY push button. One unique feature of this SWAT is that if you leave out the EMERGENCY push button, the circuit ground is not needed and you can build the unit using only the tip and ring leads and run with only two wires. The single-pole switches are a lot easier to find than the two-pole switches used in SWAT/2. This SWAT is also a good one to mount into a panel in one or more layout locations.

SWAT/2: two-button control

This unit was developed to make one-hand operation a little easier, and it has proven to be the most popular of all the SWAT's. The top button causes FORWARD motion and the bottom button is for REVERSE; this is the same as with SWAT/1. Pushing both buttons causes a second set of contacts on both switches to make and connects circuit ground to the control lead (tip), thus discharging the momentum capacitor in SWAC/2 at a fast rate (emergency stop). I have been very surprised at the rate that people, even non-model railroaders, learn to use this throttle. Just show them what the buttons do and away they go.

SWAT/3: pot with reversing switch

If you like conventional control, this is the one for you. The potentiometer controls the speed, and the toggle switch is used for reversing direction. The acceleration can be fixed or adjustable just as in the other units. One of the nice features of this unit is that when you throw the reversing switch, instead of an instant direction change the loco will come to a stop, reverse, and then pick up speed at the rate set by the acceleration control or resistor. This unit can be operated with one hand after a little practice.

SWAT/4: single-pot control

When it comes to popularity with these throttles, this one rates in second place with SWAT/2 in first place. This design uses a standard potentiometer with one end tied to plus voltage and the other end connected to a minus voltage. Move the pot to the right and a plus voltage is sent to the SWAC/2, left for minus voltage and reverse; the center for near zero volts and sets SWAC/2 to stop. You can control the brake rate by how far you turn the pot in the opposite way to that you're going. When the loco stops, set the pot to center to prevent it from reversing. If you just set the pot to the center with the loco in motion, it will just roll to a stop. An EMERGENCY push button and/or acceleration control can be added to this unit if you wish.

I find this one almost as easy as SWAT/2

Fig. 6: SWAT/1

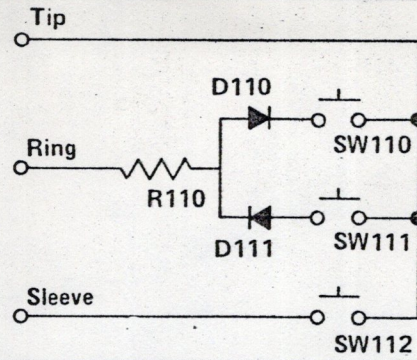
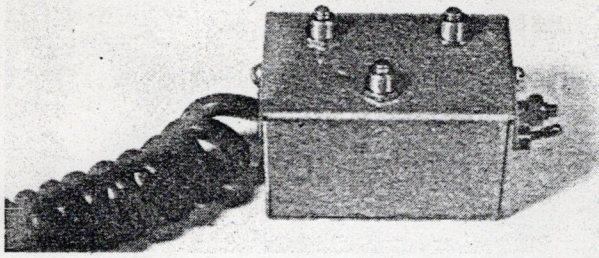


Fig. 7: SWAT/2

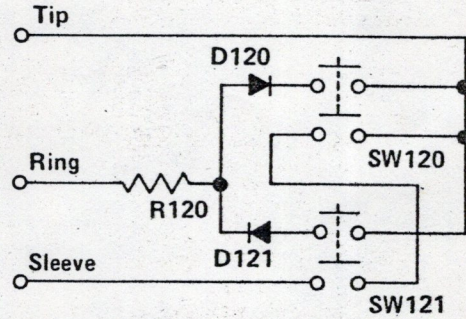
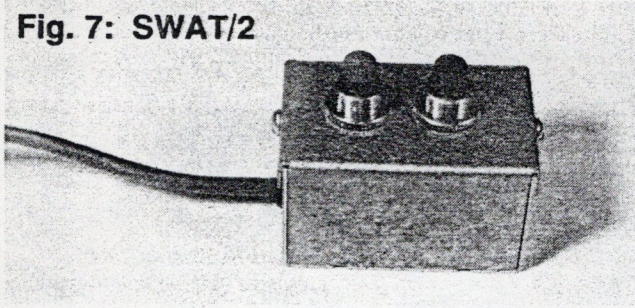


Fig. 8: SWAT/3

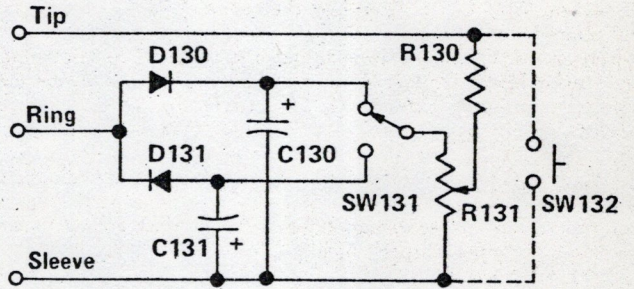
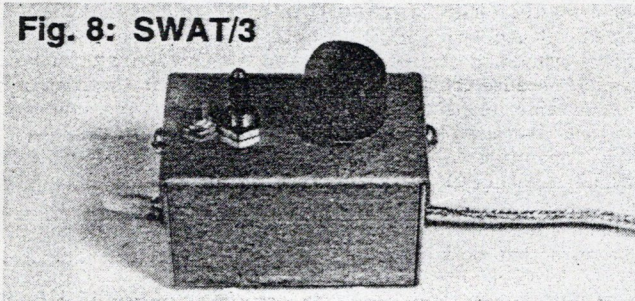


Fig. 9: SWAT/4

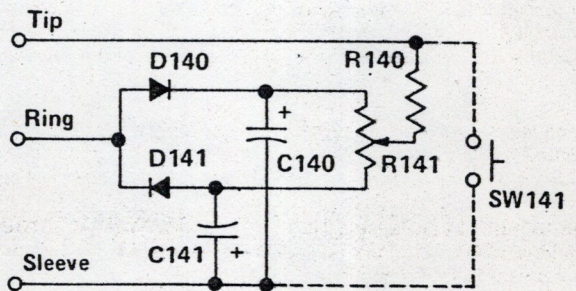
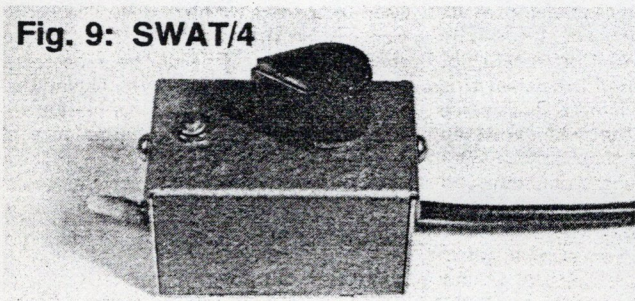
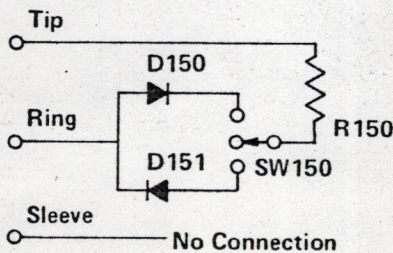
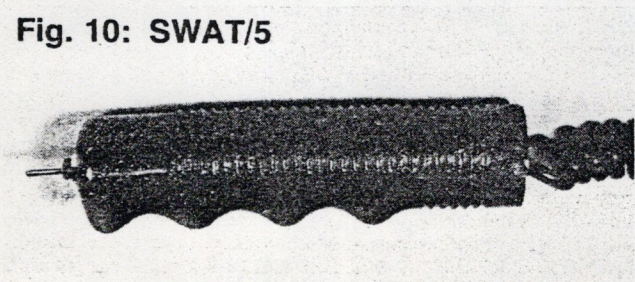


Fig. 10: SWAT/5



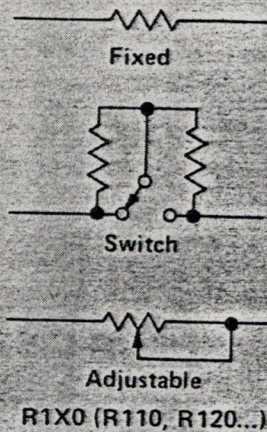


Fig. 11

SWAT parts list

1: BASIC PARTS

Case: Small metal or plastic box, like LMB No. M00 (2¼" x 1½" x 1½") or Radio Shack No. 270-230 (1½" x 3¼" x 2½") for SWAT 1 to 4; bicycle handle grip for SWAT/5—or any thing that suits you.

Connector: Standard three-wire ¼" phone plug like Radio Shack No. 274-139 (package of two).

Miscellaneous: Wire, grommets, mounting hardware and so on.

2: ELECTRICAL PARTS

C130, C131, C140, C141: 50µf, 25-volt, miniature electrolytic capacitor.

D110, D111, D120, D121, . . . : All diodes used in SWAT's 1 to 5 are 1-amp, 50-volt silicon diode, 1N4001 or equivalent.

R110, R120, R130, R140, R150: See text.

R131, R141: 5,000-ohm potentiometer, linear taper.

SW110, SW111, SW112, SW131, SW141: Push-button switch, s.p.s.t. (single-pole, single-throw) normally open.

SW120, SW121: Push-button switch, d.p.s.t. (double-pole, single or double throw); see note 1.

SW131: Miniature toggle switch, s.p.d.t. (single-pole, double-throw).

SW150: Miniature toggle switch, s.p.d.t. with spring return to center, sometimes referred to as "Momentary-off-momentary".

NOTE 1. A kit of parts for the SWAT/2 consisting of two Switchcraft DVR2206 d.p.d.t. push-button switches with different colored caps, two diodes and a 33,000-ohm resistor is available from the author at Gold Spike Lab, P.O. Box 24772, San Jose, CA 95154. Kit is No. SWAT/2k, priced at \$4.50 postpaid (California residents please add 6.5% sales tax)—Ed.

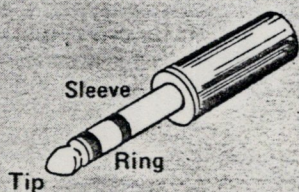


Fig. 12

to operate with one hand. Hold the box in the palm of the hand and work the knob with the thumb.

SWAT/5: one-switch control

If you thought that two buttons were not enough to run a train, how about *one toggle switch*? RMC author Jack Burgess suggested using a bicycle hand grip as a walk-around throttle handle. (Did you ever try to buy just one handle grip at a bicycle shop? I didn't have the nerve to tell the salesman why I only needed one.) Frank Geraci keeps telling me that he can build a SWAT into one of the Kodak plastic 35mm film cans; I think this would be the one.

Everyone likes this SWAT and has fun with it, even though the others were more popular. This one does not have provisions for emergency braking, which is not too big a problem if the value of R150 is kept low.

Variations on a theme

If you use all push-button-switch SWAT's (1, 2 and 5), a number of these may be connected to the same SWAC/2 at one time and not affect the operation. An example of this would be to build a number of these into control panels or have the SWAT's permanently connected on short cables around the layout. You could then start a train in one location and walk to the next spot and be ready to control the train when it arrives. You can also permanently wire SWAT/3's or 4's into a system if you add a toggle switch to turn the ring and tip leads off when the SWAT is not in use so it will not affect the operation of the other connected units.

The Walnut Creek Model Railroad Society in Walnut Creek, California, has installed a number of SWAC/2's in their layout for yard switching, plus narrow gauge and traction operations. Bill Swindell of the club's electrical committee said that each of the panels has a set of push-button switches in the panels (SWAT/1) and an extension cord with a phone plug on the end. The club members have a choice of using the built-in SWAT or building their own. Bill tells me that the members are thus coming up with all kinds of ideas on how they want their own SWAT's built. One of the members built a SWAT/1 and SWAT/4 into the same unit. He then switches from one to the other with a small toggle switch. Another built a SWAT/5 with a rocker switch and added an emergency push-button switch. Still another used a slide pot in a SWAT/4.

Another of the Walnut Creek members, Bob Rufenacht, especially appreciated the SWAC/2's true one-hand operation, as he lost one of his hands in a railroad accident. (Bob serves as an inspiration to other handicapped modelers by such accomplishments as building working motor-powered Mars lights into his HO diesels.)

The several walk-around throttles reviewed here are by no means the limit of the different types of SWAT units that can be designed. We are working on a number of other SWAT's for the future. In the November 1975 RMC, Jack Burgess showed how to put a rotary switch into a "live steam" brake stand casting. One South Side Switching & Sipping Society member, Howard McKinney, purchased one of

these, and we plan to build an SST/7-type unit for his SWAC/2. There is enough power in the 12-volt a.c. lead (ring) to run a few external circuits. This will be one way to "have your cake and eat it."

Another thought is to build a small ultrasonic or radio receiver that could decode signals from a battery-powered walk-around throttle. This would be one way to make a wireless walk-around throttle.

SWAC/2 and SWAT costs

The cost of building a SWAC/2 depends on a number of factors, such as what features you want, what type of cabinet you use and how fertile your junk box is. If you build a bare-bones SWAC/2 and have parts like the transformer and relay on hand, you can build a SWAC/2 with a SWAT/1 in a control panel for less than \$50. This is the way the Walnut Creek Model Railroad Society built their SWAC/2's and saved the cost of the cabinets by building the units on a piece of heavy plastic. If you add all of the "bells and whistles" and buy most of the parts, the cost could run \$90 to \$100.

SWAT costs also depend on what you built and what you have in the junk box. SWAT/1 could be built out of three old door bell push-button switches. If you buy all of the parts, the cost will fall somewhere between \$2 and \$10. The cost of the cord must be added if you do not build the SWAT into a control panel.

Summary

The design of SWAC/2 allows a modeler the freedom to—as they say on one of the TV ads for hamburgers—"have it your way." Almost every modeler that I've talked to about applications of this control system has some type of throttle problem that is peculiar to his or her layout. In almost every case, one of the five SWAT's described in this article or a variation would solve the problem. Not all of the South Side Switching & Sipping Society members went along with the "standard" cabinet, for example. Out of the seven that were built, only four were the same. The others were in different types of cabinets and laid out to fit into existing layout spaces.

In the closing lines of the SST/7 article (October 1975 RMC), I stated that as advancements were made in the electronic state-of-the-art, further progress would be possible in our control equipment. Three new devices have helped to make SWAC/2 a reality. The power-on and overload lamps have the lowest reliability of all the components used in the SST/7. SWAC/2 uses solid-state LED's that have a very long life, are more rugged and cost about the same. The power Darlington output transistor (Q4) and the FET op amp (IC1) were items that were not generally available when the SST/7 was designed. The SST/7 was first designed without op amps because of their high cost at that time (1970-71).

The SWAC/2 throttle system thus represents another step along what I feel is an unending path toward better model railroading through improvements in existing hardware (e.g., throttles) as well as in the availability of more options for the solutions of problems faced by contemporary model railroaders.

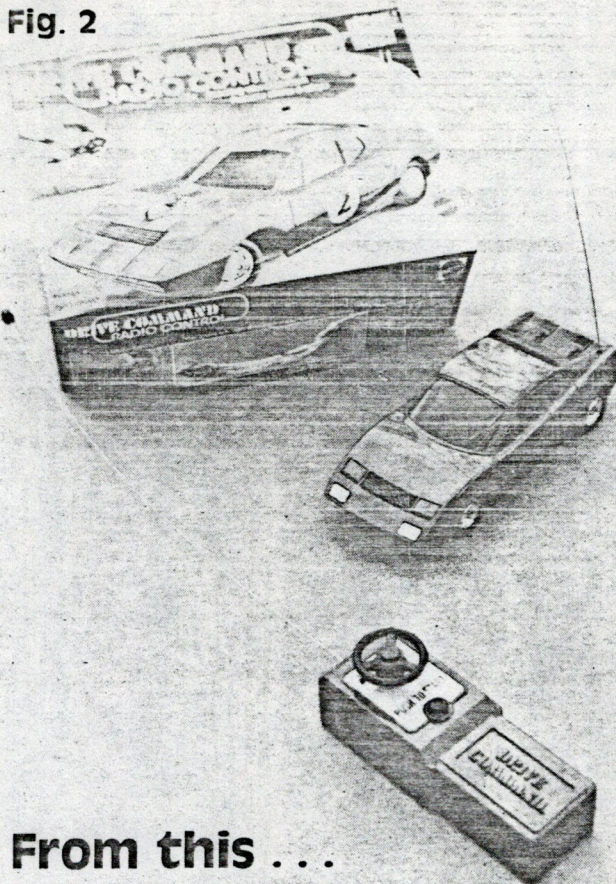
Radio control for SWAC/2

In the past several years, many different approaches to model train control have been proposed, designed and produced. These include sophisticated cab-type throttles such as the SST/7 (September 1975 RMC), walk-around throttles such as the SWAC/2 (August 1977 RMC), radio-control locomotives (May 1976 RMC), carrier control (Alpha-tronics, Dynatrol, Onboard, etc.) and radio-control throttles (MRC, and December 1978 and October 1979 RMC).

As the operator of a medium-size layout and locomotive fleet, I felt the carrier-control and radio-control systems were at times too restrictive on the combinations of motive power able to be run at any one time. These systems permit tremendous operating flexibility (even allowing cornfield meets) but tend to be fairly expensive. Most also require the installation of receivers in all powered equipment and usually modifications to all lighted equipment.

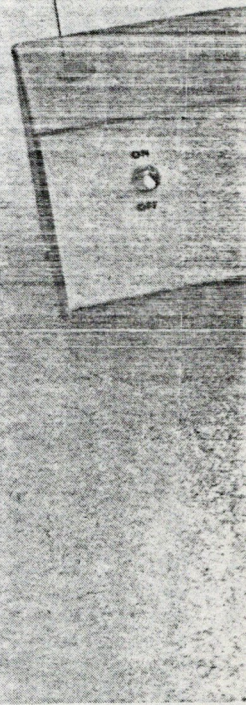
I had decided to use the traditional block control initially, while planning and progressively installing a microprocessor for control of block power assignments and signaling. This system will allow the use of many commercial and "custom" throttles such as Fiehmman's SST/7. It also does not require modification to motive power or rolling stock, allowing your friends to operate

Fig. 2



From this ...

Fig. 3



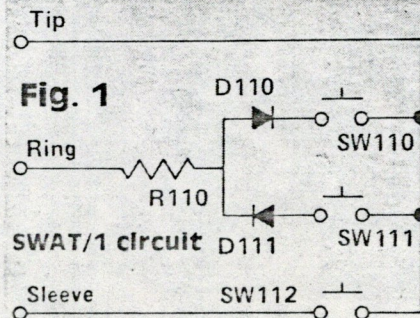
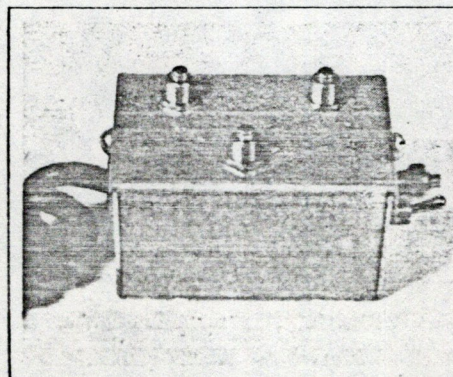
their equipment on your railroad.

The cab and walkaround throttles can be used on any railroad wired for block control. Control is limited to a fixed or tethered position in the cab type, or to a more useful walk-around control as in Don Fiehmman's SWAC/2 design. The SWAC/2 allows the operator to unplug the cable and move to a new position closer to the locomotive without affecting speed or direction. I purchased the circuit board for this throttle and found the assembly easy and operation excellent with repowered, regearred and ready-to-run locomotives.

The various walkaround throttles described in the SWAC/2 article allow one-hand operation, but even with a small group

in the layout aisles (they're never too wide), I found that someone soon became entangled in the cords. After several months' use, the only feature that didn't have me totally satisfied was the remaining cable from my handheld throttle to the layout. Radio-controlled operation obviously deserved more investigation.

The design of the SWAC/2 permits as few as two buttons to control the throttle output and polarity. The basic SWAT/1 as described in the September 1977 RMC article uses a



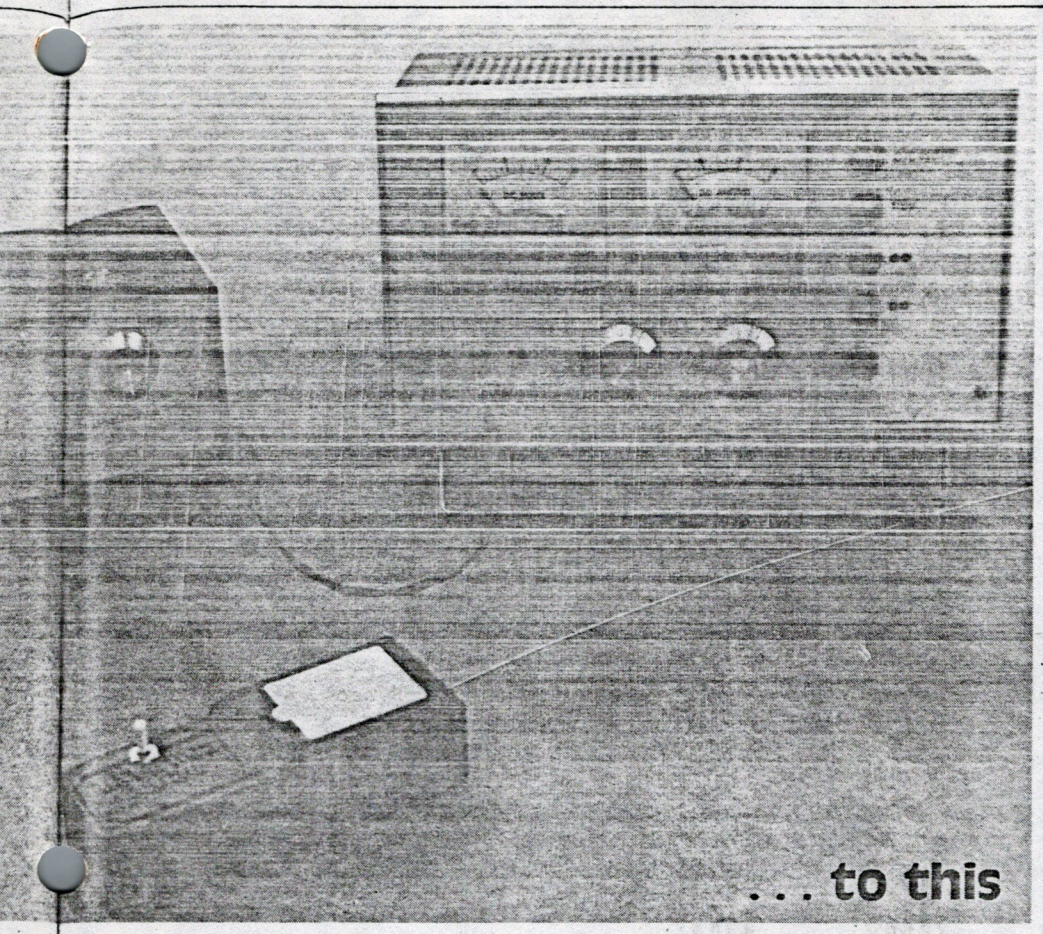
What you'll need:

R/C cars:
 Mattel Drive Command Ferrari 512 (2444-3, 27.145 mHz)
 Porsche 935 (1106; 49.86 mHz)
 Lancia (1104, 27.145 mHz)

Receiver components:
 Case Radio Shack 276-260 or equiv.
 Radio Shack 276-1392
 Radio Shack 276-1076
 Radio Shack 276-1101
 Radio Shack 271-1716
 Radio Shack 275-1547
 Radio Shack 275-612
 Radio Shack 274-413
 Radio Shack 274-139 (see text)

Transmitter components:
 Dpdt center-off toggle Radio Shack 275-620
 100k ohm resistor

Note: All resistors are minimum 1/4-watt 10%.



Relatively inexpensive
Mattel radio-controlled
car components can be
adapted to control
Don Fiehmann's SWAC/2
throttle/**Robert Bucklew**

Fig. 4

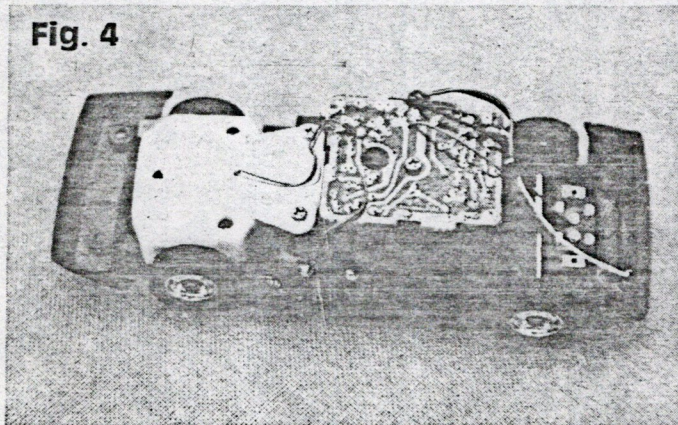
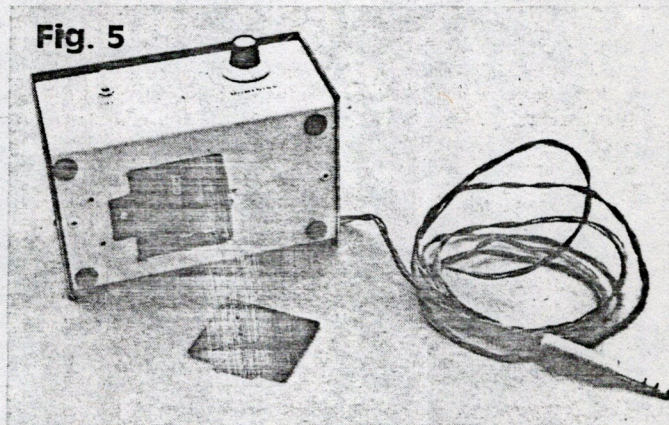


Fig. 5



third button for emergency stop (see Fig. 1). Control of these contacts is certainly possible with commercial radio-control equipment using linkages and servos as described in Andy Sperandio's article in the December 1978 RMC, but I was looking for a less expensive method. Due to the simplicity of the SWAT/1 design, an all-electronic approach is possible. Silicon-controlled rectifiers (SCRs) can replace switches SW110 and SW111. All that is then needed is a two-channel transmitter/receiver to alternately turn on the SCRs.

The toy industry has offered several relatively inexpensive radio-controlled vehicles in the last few years. I looked for one with two

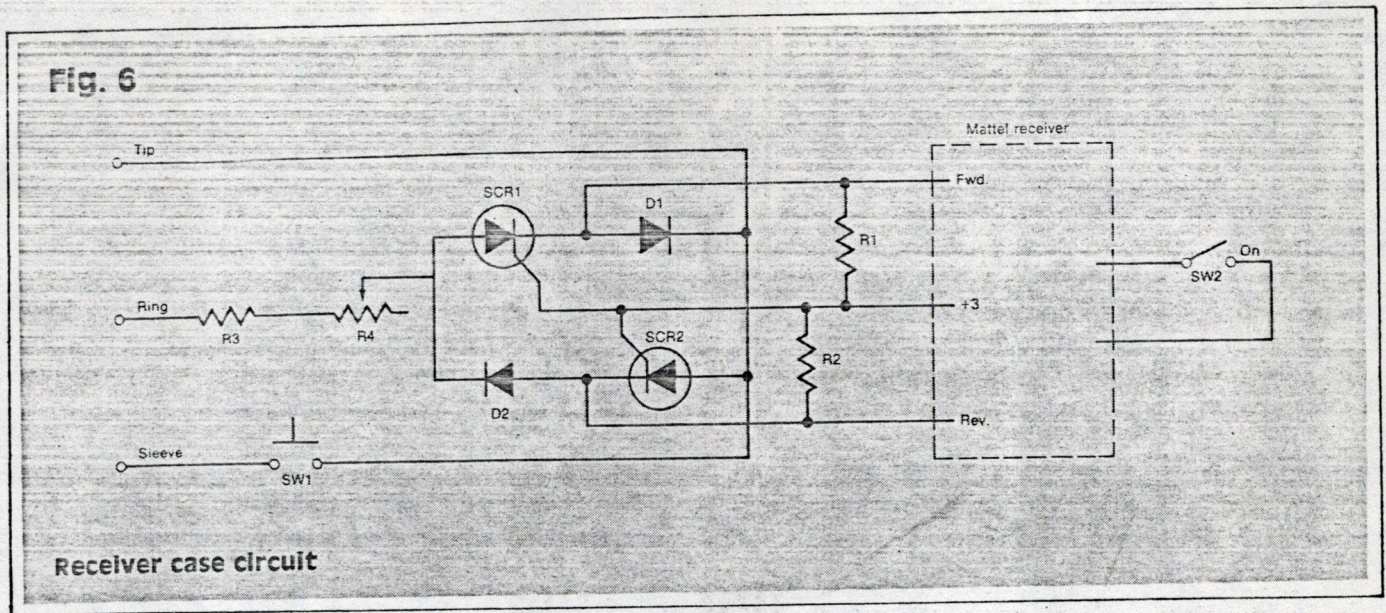
channels and purchased the Drive Command™ marketed by Mattel*. The radio operates on 27.145 MHz and provides two outputs proportional to the position of a steering wheel on the hand-held transmitter (see Fig. 2). I modified the transmitter to allow the two SCRs to be individually controlled. No changes are required to the receiver circuit itself.

Construction

Fig. 3 shows the case used to house the receiver and SCRs for control of the SWAC/2 throttle. The case provides mounting surfaces for the components and helps improve the finished appearance.

Start by carefully removing the body and antenna from the car chassis. The three wires from the receiver to the front drive axle can be quickly unsoldered with a hot iron (refer to Fig. 4). Remove the drive axle from the chassis and cut the wires to the on-off switch. Cut the receiver from the chassis using a razor saw or knife, making sure to include the entire battery compartment and enough chassis to allow attachment to the case. I cut a hole in the bottom of the case which allows access to the battery compartment cover for easy battery replacement (see Fig. 5). The receiver can then be fastened to the case with sheet metal screws.

*Mattel, Inc., Hawthorne, CA 90250



The circuit for the remainder of the receiver case is shown in Fig. 6. The SCRs, diodes and resistors can be mounted on a small perforated board which is later fastened inside the case. Refer to Fig. 7 for the board layout. The values of R1 and R2 may have to be changed later when fine-tuning the throttle, so allow room to add resistors in parallel.

I used a three-conductor stereo plug on a ten-foot cable for connection of the receiver to the SWAC/2 control unit. This also permits flexibility between the radio and regular walkaround throttles and requires no modifications to the standard control unit.

The 50k (50,000-ohm) potentiometer (R4) replaces R110 in the original SWAT and allows adjustment of the throttle momentum. The 15k resistor in series limits the momentum control to a very fast but controllable yard rate. Switch SW1 provides an emergency stop not available on the hand-

held transmitter. Switch SW2 turns the receiver off, saving battery power when not in use. Note that turning off the receiver while the train is in motion will not stop the train, but is analogous to unplugging the SWAT walkaround throttle. Two small holes with rubber grommets allow the receiver antenna to protrude from the top of the case and protect the cable to the controller. Fig. 8 shows the layout of the completed receiver case.

The modifications to the hand-held transmitter change the proportional control of the steering wheel to a simple two-output control. This allows you to turn on one SCR or the other, but not both, duplicating the two-button control of the SWAT/1. Two d.p.s.t. pushbuttons could be used for this function, but I chose to use a d.p.d.t. center-off toggle switch. This switch allows easy one-hand, one-thumb operation.

The transmitter as supplied has two controls: the steering wheel (potentiometer) and

a pushbutton on-off switch. These have a common connection and schematically can be represented as shown in Fig. 9A. Fig. 9B shows how to hook up the toggle switch, while Fig. 9C shows the alternate pushbuttons.

Carefully remove the potentiometer from the transmitter using a hot soldering iron. The pushbutton switch is easily removed, leaving the leaf switch contact in place. Room to mount the toggle switch or pushbuttons in the transmitter is made by cutting the ribs in the battery compartment and rotating the battery 90° (see Fig. 10). The cover rib will also have to be removed to provide additional clearance. Three wires then connect the toggle or pushbuttons to the transmitter circuit as shown in Fig. 9. I cut a piece of sheet styrene to cover the face of the transmitter, closing the holes for the steering wheel and pushbutton (Fig. 11).

You can now check the operation of the

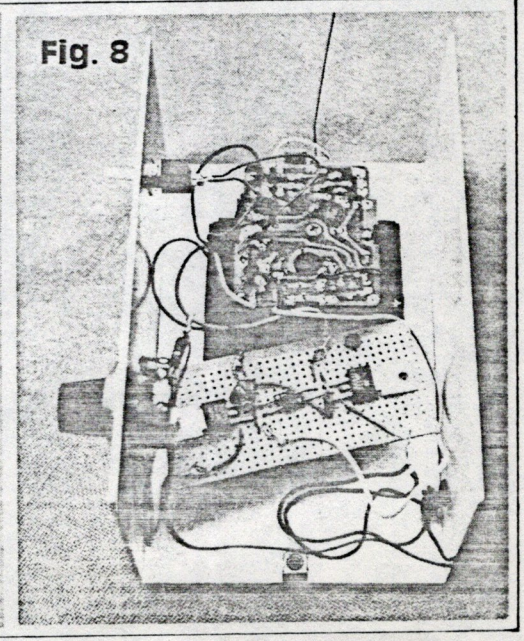
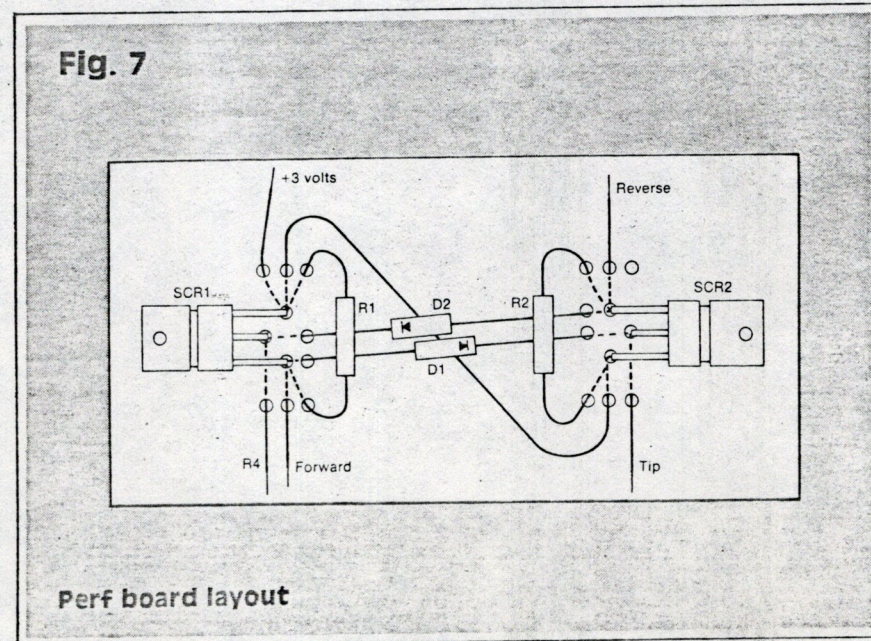
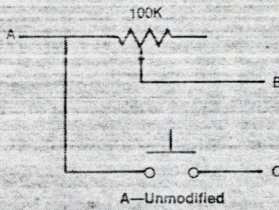


Fig. 9A



Transmitter

Fig. 9B

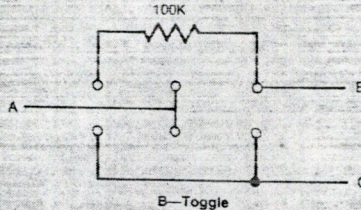
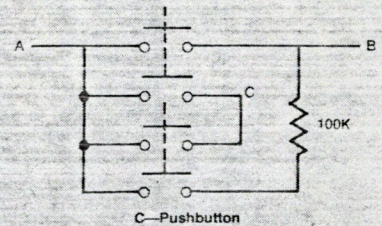


Fig. 9C



transmitter and receiver. Plug the receiver into the SWAC control unit and turn both on. With the transmitter switch in the center position, the voltage should remain constant. If the voltage drifts up or down with the transmitter off, first reduce the sensitivity of the receiver by turning its trimpot counter-clockwise. If the problem persists, substitute a smaller value resistor for R1 or R2. This will drain the batteries faster, but makes it more difficult for the SCR gates to accidentally misfire. Change the resistors in steps, using the highest value which prevents misfiring. Resistors R1 and R2 can be replaced with any value between 10 and 20 ohms. When checking the operation, note that a 60-ohm resistor in parallel with the 20-ohm resistor results in the circuit equivalent of 15 ohms, while a second 20 ohm resistor in parallel results in a circuit resistance of 10 ohms. Once satisfactory operation is obtained, these can be permanently added in parallel, or R1 and R2 can be replaced with an equivalent value.

Putting the transmitter in either operating position should result in a continual change in the voltage level and control of the SWAC reversing relay. Centering the switch should again result in a steady voltage. Operation is similar to the SWAT/1, so that

holding the switch in one position will result in a continual increase in speed. The rate of acceleration can be controlled with the momentum potentiometer. The opposite direction of the switch slows the locomotive and then activates the reversing relay.

The Mattel equipment is now available in three models operating on two different frequencies, allowing independent radio operation of two throttles at the same time. (See the materials list for details.) Once the original concept was proven using an add-on unit, I constructed a dual SWAC/2 unit complete with integral radio units operating from internal power supplies. This eliminates the need for batteries except in the hand-held transmitter. I have found that the nine-volt battery in the transmitter will last for about 15 hours of operation. Your experience may be different due to your layout size or operation, as the battery is only in use during a change in speed or direction. Switching movements will require more frequent battery changes.

Using SCR's to connect inexpensive radio components to the SWAC/2 is certainly not the only possible method. One likely solution would be to optically couple the receiver to the SWAT circuitry.

I've used this throttle on my bedroom test

loop, my basement railroad, on several friends' layouts, and on RMC Editor Tony Koester's railroad. Position of the receiver does not seem to be critical, but common sense indicates a central location is best, even if under the layout. A longer receiver antenna does not seem to result in more reliable operation, but the transmitter antenna length does. I used the antennas provided with the Mattel car and find operation very reliable. Fig. 12 shows the relative size of the transmitter compared to a SWAT/1 in the smallest size plastic case from Radio Shack. I use the transmitter at my side and hold it so the antenna angles away from my arm. However, if the transmitter antenna is held close to your body, the receiver may fail to respond.

I have been pleasantly surprised by the ease of operation which friends have demonstrated while using the radio throttle, even when not previously familiar with the two-button concept available with the SWAC/2 throttle. Cost of this radio-control project will vary from \$30 to \$40 (not including Fiehmman's SWAC, of course) depending mostly upon your source for the Mattel car. I hope you find building and operating this throttle accessory as easy and enjoyable as I did.

Fig. 10

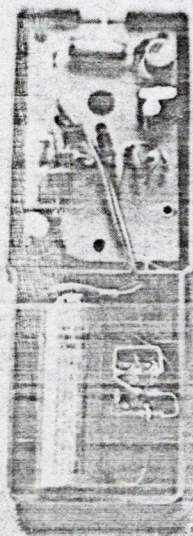


Fig. 11

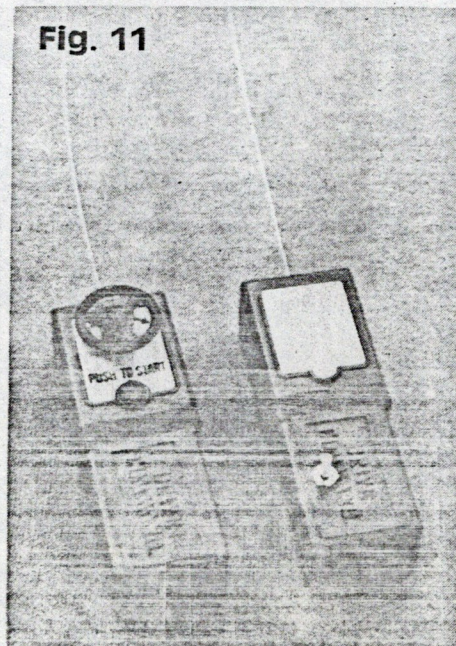
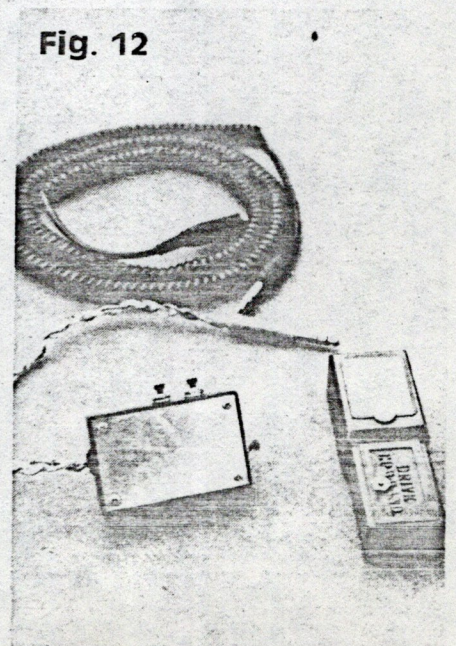


Fig. 12



The SWAC/2 throttle article was printed in August, 1977, RMC. The story also showed a number of different types of hand-held throttles that could be used with SWAC/2. They were the SWAT/1 to SWAT/5. This was only a start to the types of hand-held throttles that could be built. In the September, 1980, RMC Robert Bucklew showed how to build a SWAT using the insides of an R/C (radio controlled) model car. This allowed him to control the SWAC/2 by radio control.

One thing the SWAC/2 throttle system is good at is running a switching yard. One of the main reasons for this is that you operate most of the SWAT's without looking at them. This is very handy when switching, because you can watch the cars and engine, and not the throttle controls as you must with most throttles. The most popular of the SWAT's so far has been SWAT/2. This is the two button throttle.

Some of the best ideas since the publication of the SWAC/2 articles have come from people using the system. The inspiration for the one in this article comes from the Walnut Creek Model Railroad Society. This SWAT, dubbed the SWAT/6, is based on a design many of them are using for switching.

The circuit looks a lot like the SWAT/3 (September, 1977, RMC), which uses a knob and pot to control speed and a toggle switch to control direction. The SWAT/6 also uses a pot to set the engine speed. The big difference is in the type of direction switch used. The switch in this SWAT reverses the trains direction each time it is pressed. The speed pot sets the maximum speed and a trim pot sets the acceleration rate. This allows you to set a maximum speed and then switch directions with the push of a single button. The SWAC/2 takes care of the deceleration, stopping, reversing, and then accelerating back to the set speed. Once set, the speed and acceleration rates are all done automatically. All you have to think about is when to change directions.

There are two other features that you can add to the SWAT/6. One of them is the "parking brake." This is a toggle switch that also acts as an emergency stop. Once the toggle is turned on (down), the engine will come to a stop and hold until the switch is turned off (up). When turned on, the engine will resume the speed set by the speed pot.

The second feature is the power-on LED(s). Here you can either use one of the two-color

(red/green) LED's or two separate LED's. The advantage of the two-color LED's is that you can see the direction the SWAT/6 is set for, even when the parking brake is set. Both of these are options and can be installed now, later or left out.

Another nice feature is that *all* of the parts used to build this SWAT/6 are available from Radio Shack—or at least, they were when I built the test model.

It is interesting to watch an engineer run my Sierra City yards with the SWAT/6. You can hold this unit in one hand, use your thumb to switch directions, and still have a finger or two free to operate the turnout pushbuttons. You can run the whole yard with one hand and hold your cup of coffee in the other hand. (Now you know why we call our group the South Side *Switching and Sipping Society*.)

Circuit Description

The switch used for reversing is called a "push-on, push-off" type of pushbutton switch. Actually, the switch is not on/off, but a single-pole double-throw (SPDT) type switch. The contacts of this switch transfer from one side to the other each time it is oper-

SWAT / 6 parts list

Plastic case with metal front: Radio Shack Experimenter box Cat. number 270-230.

Phone Plug, three circuit: Radio Shack Cat. No. 274-139. This number is two in a package.

SW 601: Direction Control, Single Pole Double Throw (SPDT) Miniature Push-on Push-off Pushbutton Switch

SW 602: Parking Brake, SPDT Flatted Lever Switch. Radio Shack Cat. No. 275-635

R 601: Speed Control, 5K ohm linear Pot Radio Shack Cat. No. 271-1714

R 602: Acceleration Control, 100k ohm small trim pot. Radio Shack Cat. No. 271-220

R 603: 1000 ohm 1/2 watt resistor (5% or 10%). Radio Shack Cat. No. 271-023

LED 601: Tri-color LED Radio Shack Cat. No. 276-035. A single red and green LED can also be used.

C601 & C602: 22 uf 35-volt miniature electrolyte capacitor. Radio Shack Cat. No. 272-1014

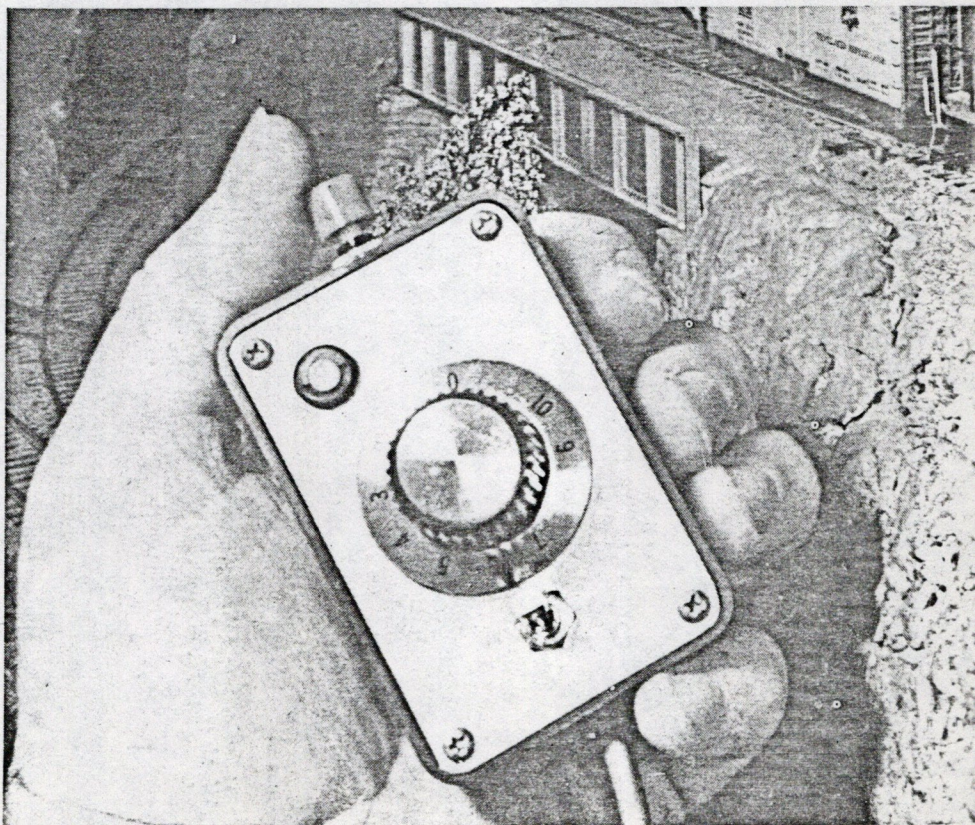
D601 & 602: 1 amp, 50 volt silicon diode 1N4001 or Radio Shack Cat. No. 276-1101

Other Items: Knobs and wire to suit.

Note: Gold Spike Lab (P. O. Box 24772, San Jose, CA 95154) does not carry any of the above parts. Printed Circuit cards for SWAC/2 are still available from Gold Spike Lab at \$12.50 each.

SWAT 6

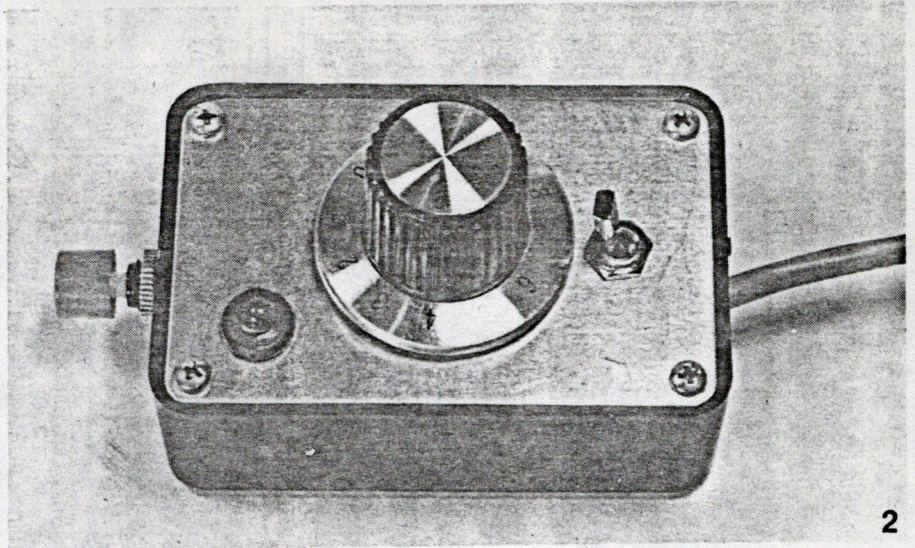
If you built the SWAC/2, there's another SWAT hand-held throttle to add to the list/**Don Fiehnann**



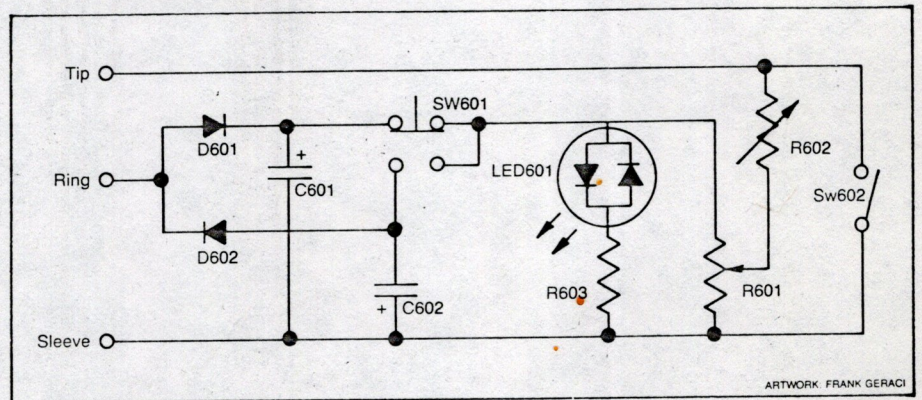
ated. This switch is connected to reverse the polarity of the power fed to the speed pot each time the switch is operated. A second pot is used to set the acceleration rate. I used a 100K trim pot and mounted it on the back of the speed control pot. With a small hole in the back of the case, you can adjust the setting of this acceleration control pot. The acceleration pot does not need to be adjusted very often. The only time would be if you had a big change in speed of the locomotive being used.

The LED's can either be two separate LED's, one green and one red, or one two-color LED. Radio Shack calls this LED a "tri-color LED." (You can also make this LED turn yellow if you use it on a.c.) I connected my unit so it would light green if it was set for forward and red for reverse. That would mean that the short lead on the two-color LED would be connected to the output of the pushbutton switch. To be honest, I left the two wires to the LED off until the unit was finished and determined the correct connection after I turned power on. One word of advice on soldering LED's. Try to do it fast with a hot iron; too much heat too long will send you back to Radio Shack for another LED! One way to help is to leave the leads long on the LED, and solder the wires on near the ends away from the LED. You can also hold the leads of the LED with a pair of long nose pliers at a point between the LED and the part of the lead to be soldered. This will keep the heat from getting to the LED as it is soldered.

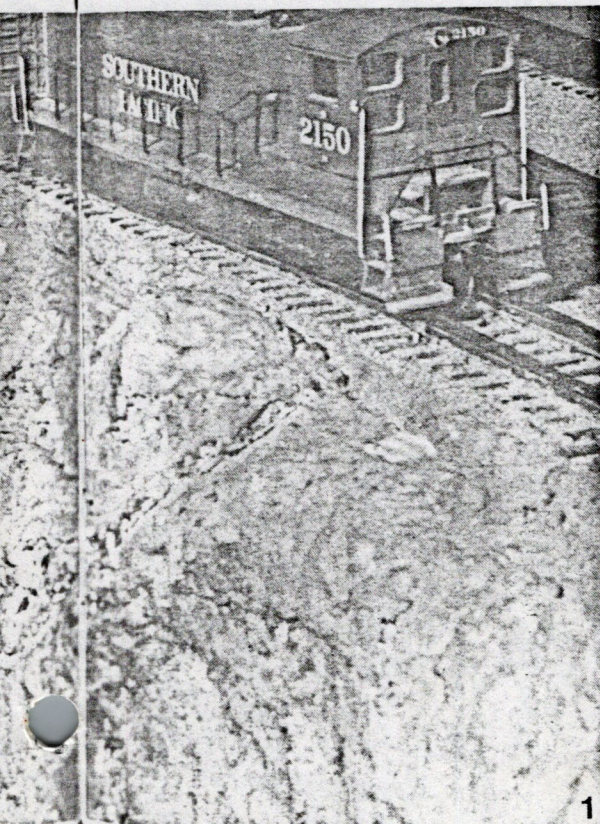
When finished, plug it into your SWAC/2 and start switching with your favorite switcher. Set the trim pot for the best acceleration at the speed you work the engine. ☺



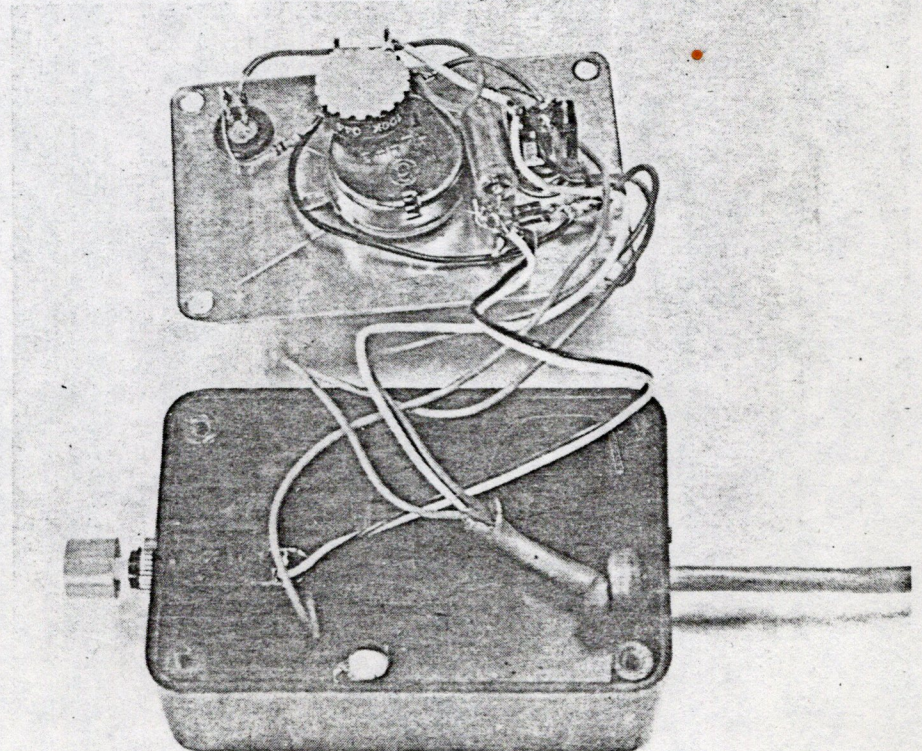
PHOTOS: DON FIEHMANN

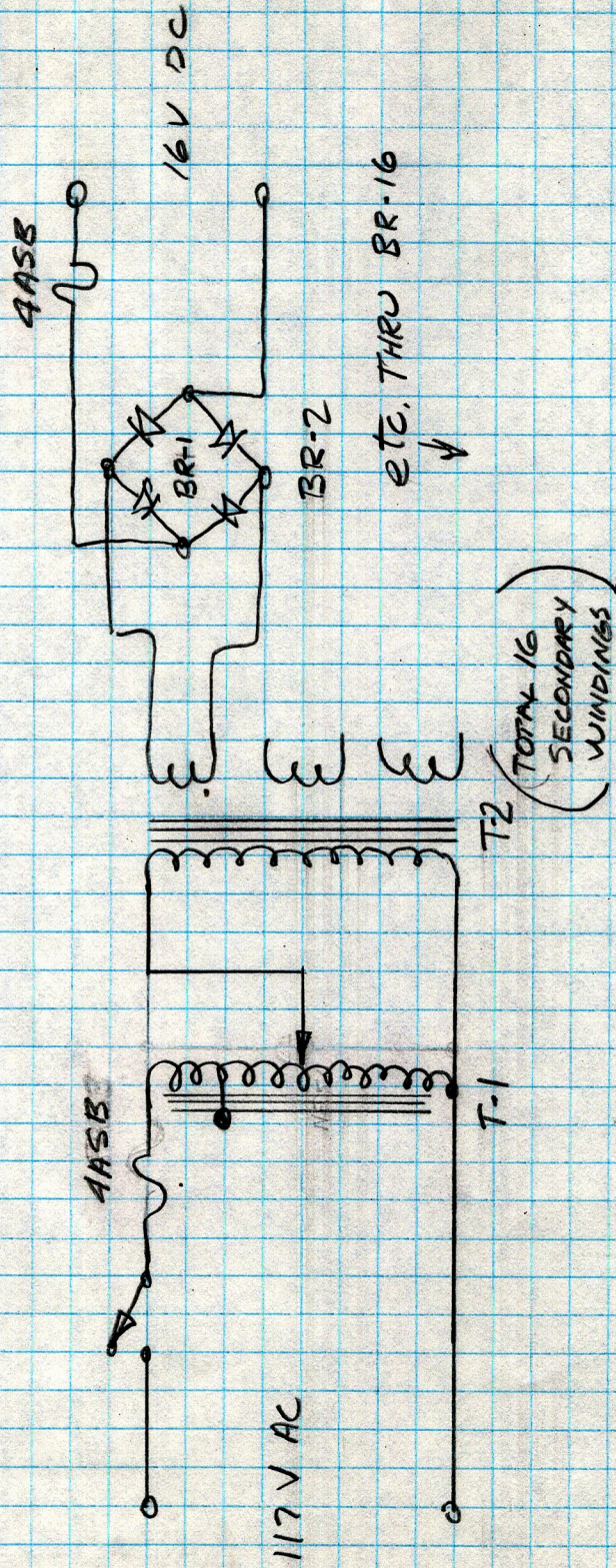


ARTWORK: FRANK GERACI



RAILROAD MODEL CRAFTSMAN

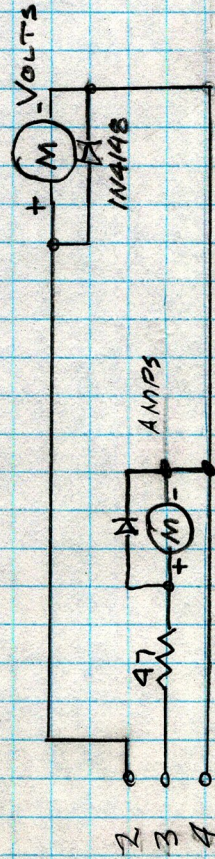
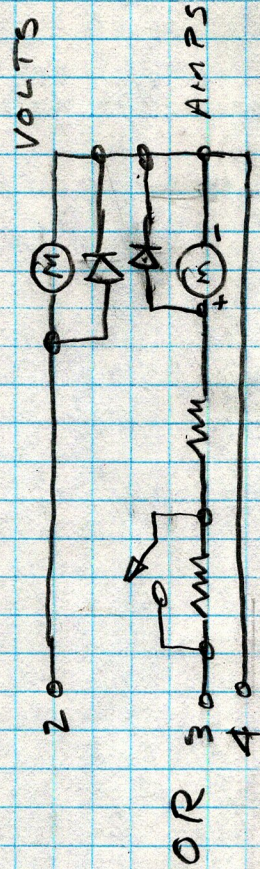
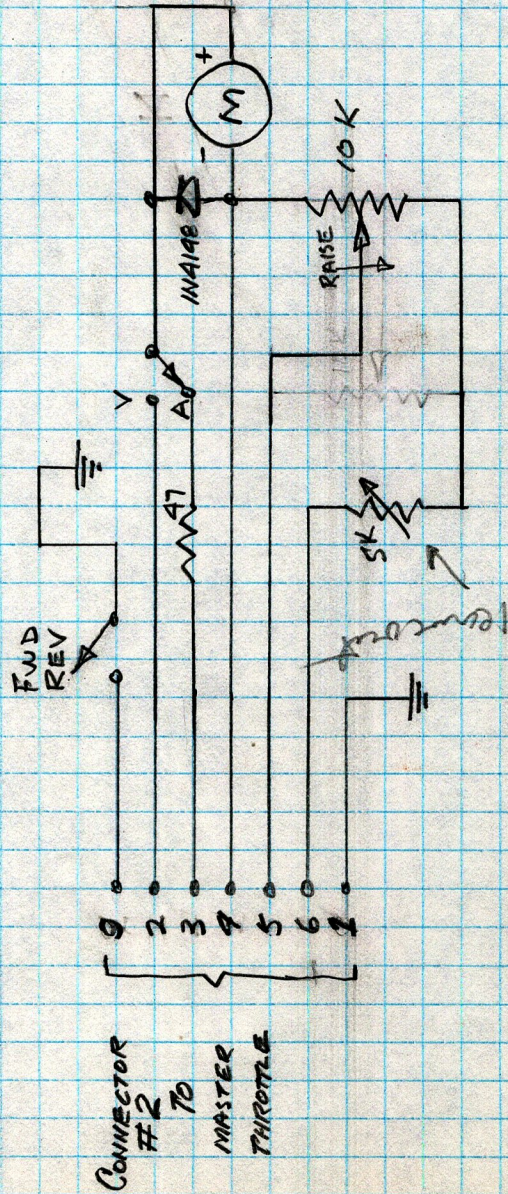




NOTE: 1) BR-1 THRU BR-16 RATING 7 12 A @ 50V

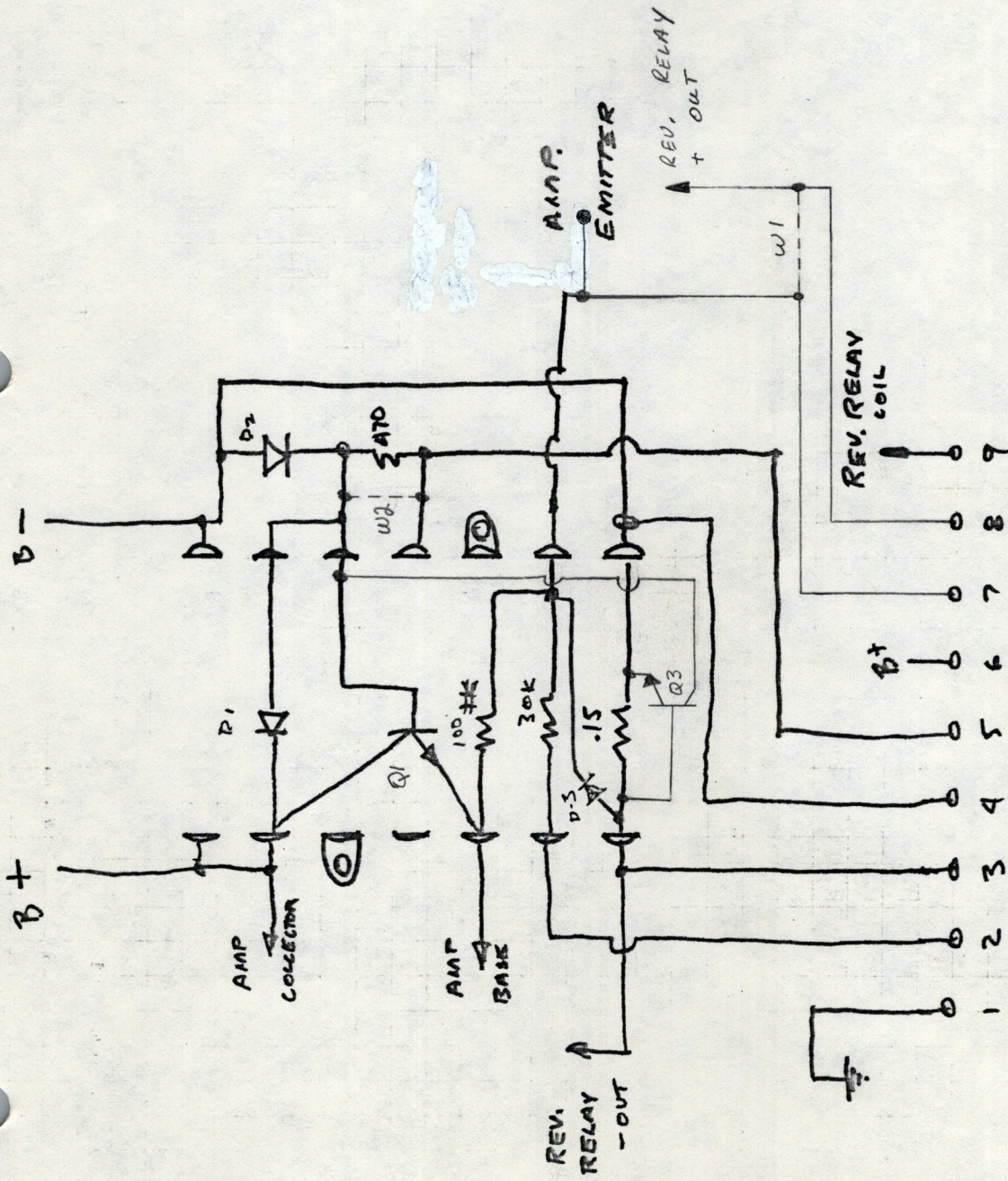
2) T-1 7 A POWERSTAT

POWER SUPPLY FOR THROTTLIES



THROTTLE -- CAB UNIT

4-1-77



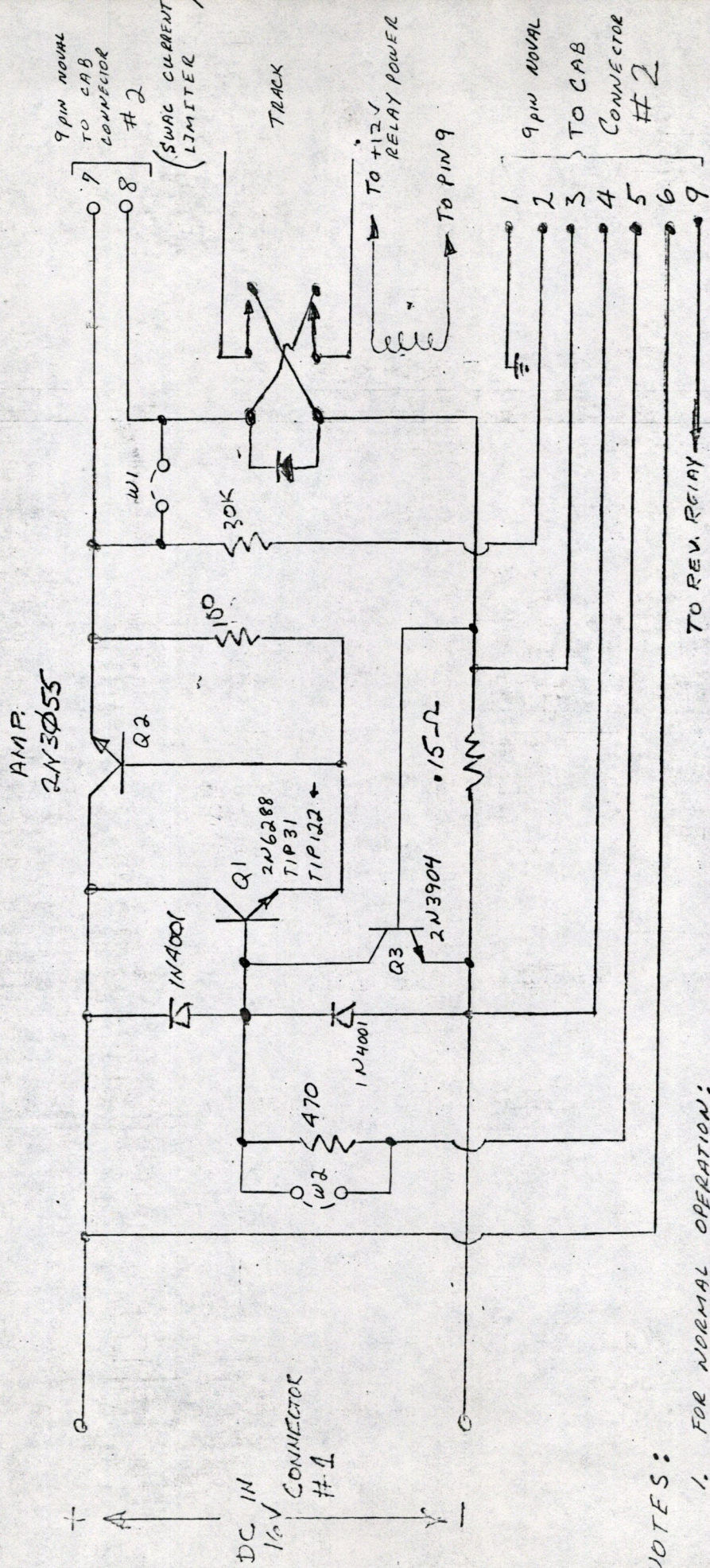
D1, D2 = 50V PIV @ 1A
 D3 = 50V PIV @ 3A

CONTROL CONNECTOR

MASTER THROTTLE

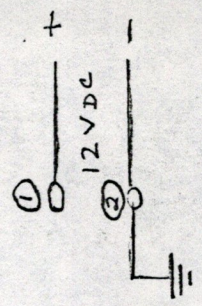
COMPONENT AND WIRING LOCATION

ADD W1, W2, Q3
 9-28-83 DOS
 A-1-77 MC



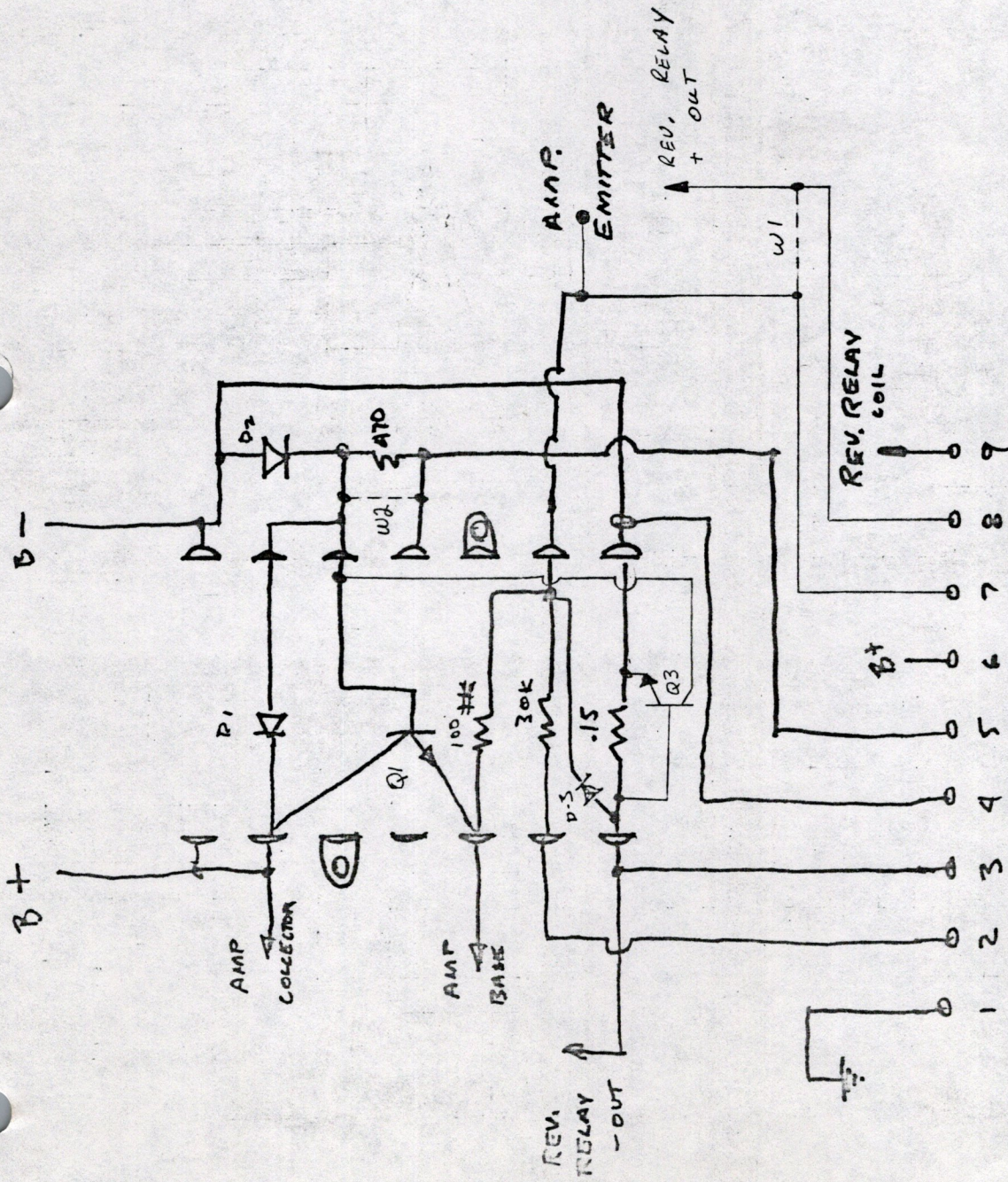
NOTES:

1. FOR NORMAL OPERATION:
W1 - INSTALLED, W2 - NOT INSTALLED, Q3 - NOT INSTALLED
2. FOR SWAC OPERATION:
W1 - NOT INSTALLED, W2 - INSTALLED, Q3 - NOT INSTALLED
3. Q3 LIMITS OUTPUT CURRENT TO APPROXIMATELY 4 AMPERES.



MASTER THROTTLE CIRCUIT

9-28-83 DOS ADD W1, W2, Q3
4-1-77 MK



D1, D2 = 50V PIV @ 1A
 D3 = 50V PIV @ 3A

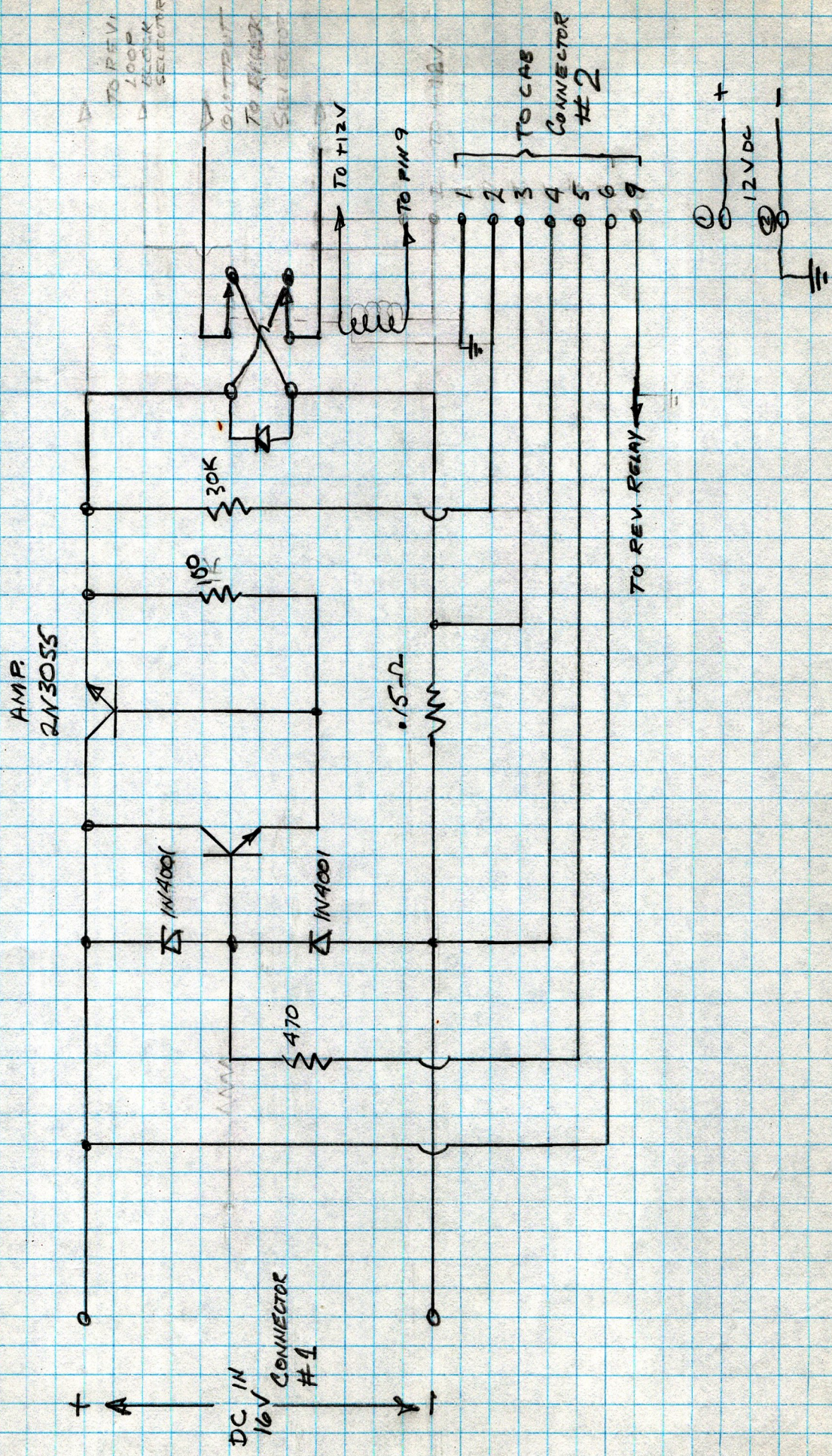
MASTER THROTTLE

COMPONENT AND WIRING LOCATION

ADD W1, W2, Q3 9-28-83 DOS
 A-1-77 KC

Not in
Service

Ship via Southern



AMP.
2N3055

30K

100

IN4001

470

0.15Ω

DC IN
16V
CONNECTOR
#1

TO REV.
100P
SELECTOR

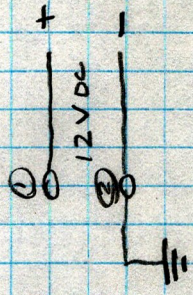
TO +12V
100P
SELECTOR

TO +12V

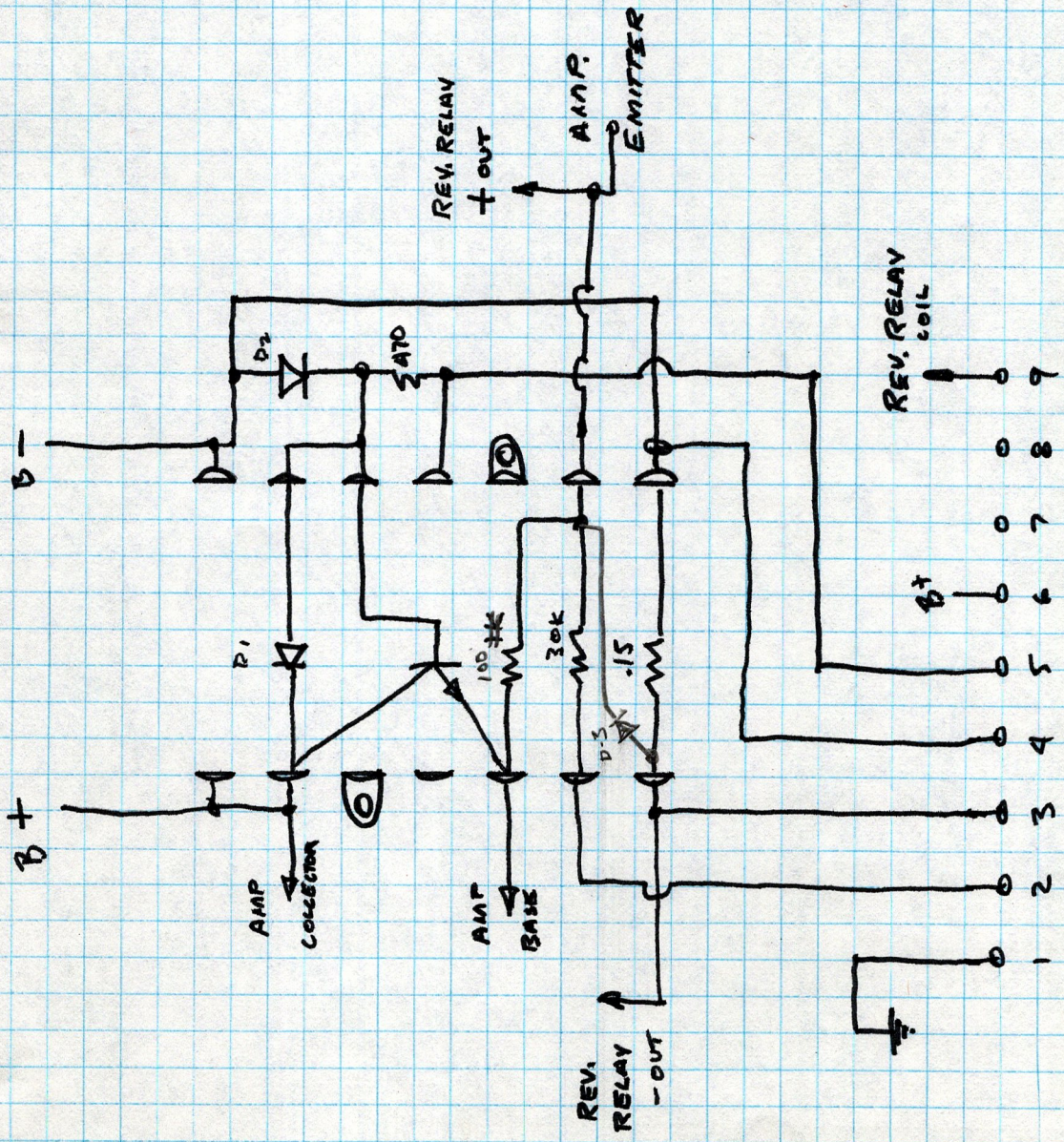
TO PIN 9

TO CAB
CONNECTOR
#2

TO REV. RELAY



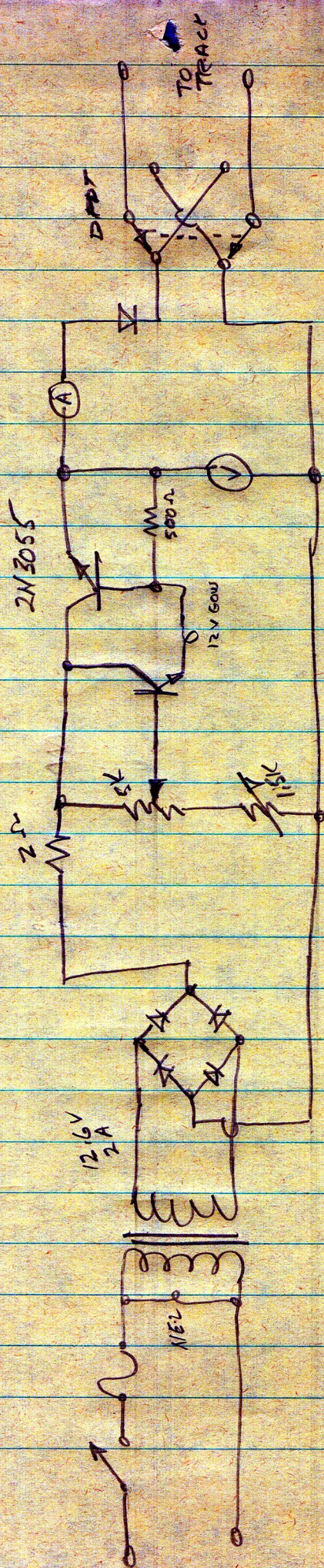
MASTER THROTTLE CIRCUIT



D1, D2 = 50V PIV C1A
 D3 = 50V PIV @ 3A

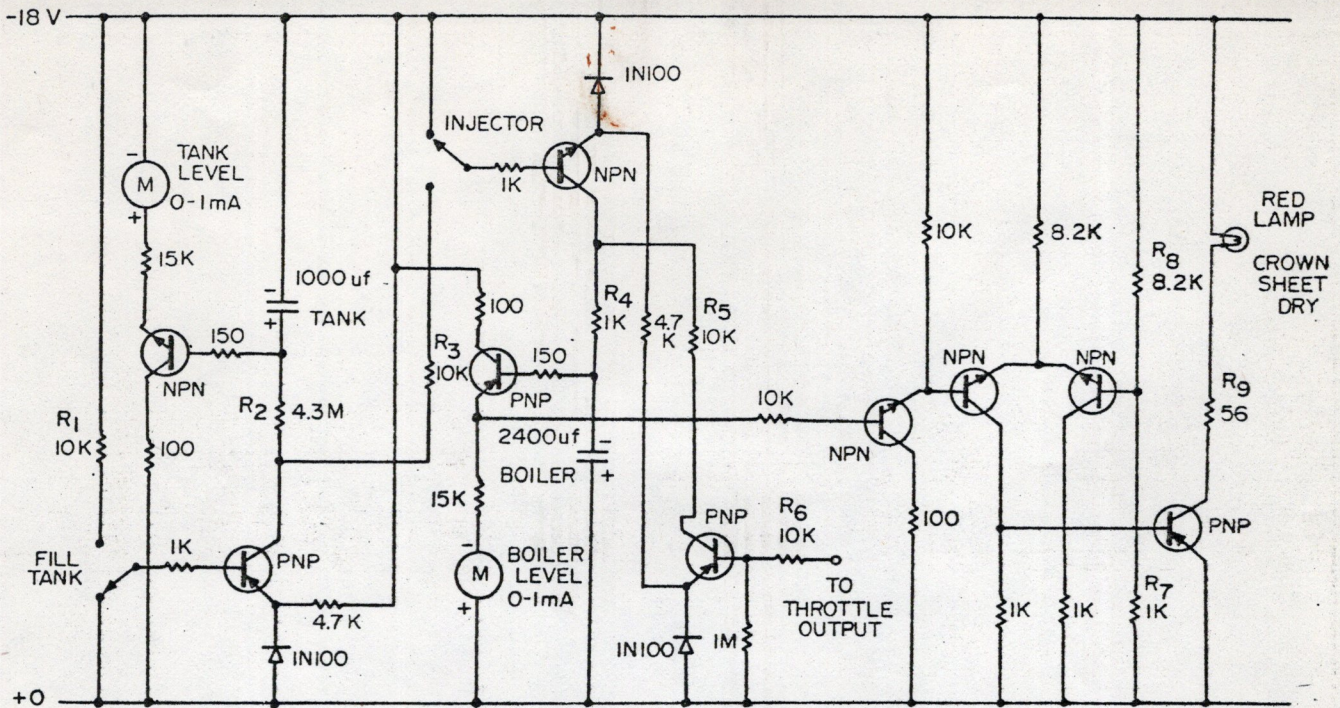
MASTER THROTTLE

COMPONENT AND WIRING LOCATION



THROTTLE
MAIN LINE CAB

SCHEMATIC



A WATER LEVEL SIMULATOR

OR

**SINCE THE ENGINEER HAS A TRANSISTOR THROTTLE
WE HAD BETTER GIVE THE FIREMAN SOMETHING**

by **Brian D. Pate** (Vancouver, B.C.)
and **Howard R. Pate** (N.Y.)

Here is another electronic gadget which, like momentum throttles and track occupancy circuits, can add to the realism and hence the enjoyment of pike operation. The circuitry is original, although the general idea is not. We first heard of the notion of simulating the consumption of water by a steam locomotive from John Pritchard of Los Alamos, N.M. Later, in reading the memorials to John Allen, it appeared that he had done this, too, like so many other things.

The general idea is that a steam locomotive carries a relatively large supply of water in a tender, which is refilled infrequently from water tanks along the right of way. The locomotive boiler has a smaller capacity than the tender, of course, and it is refilled from the boiler from time to time via the injector or injectors, as water is consumed to make steam. It follows that the more the throttle is opened, the faster steam, and hence, boiler water is consumed, and the more rapidly the boiler level will drop.

The water levels in the boiler and tender are simulated in this circuit by the charge on two electrolytic capacitors (labeled in the schematic "Boiler" and "Tank") of appropriate size. The voltage appearing across each capacitor is applied to the base of a transistor which is in series with a milliammeter, so that the deflection on each meter is proportional to the charge on its capacitor, and hence, to water level. In the installation of the circuitry on the Burrard Delbrook and Pacific Railway in Vancouver, shown in the photo, the two meters are turned on their sides and the faces masked, so that the deflecting meter needle now has the appearance of a changing level in a back-head water glass. The resistors, also in series with the meters, are to provide adjustment to get the amount of deflection right.

To the left of each meter in the installation, one finds a push button, labeled "Fill" for the tender and "Inject" for the boiler. These, when pushed, apply a voltage to the base of a transistor in series with the respective capacitor, which allows the capacitor to charge from the 18-volt supply. Resistor R1 or

R2 in the circuit may be changed to adjust the tender filling rate, and resistors R3 and R4 the boiler filling rate.

When the throttle, to which the circuit is attached, is opened, the increasing track voltage is applied to the base of a further transistor which then allows the boiler charge to leak at a faster and faster rate to ground. Resistor R5 or R6 may be changed to adjust the boiler emptying rate. We have found it convenient to choose the capacitor and resistor values such that the tender must be filled at least once on an express run through Burrard Division (which is 35 "smiles" long) and more frequently for a way freight, while the boiler needs filling 4 or 5 times for one tender filling. Some compromises are needed here, of course. Notice that the throttle output negative side (ahead of the reversing switch) is connected to "throttle output" in the schematic and the positive side to ground (0+). The circuit as a whole must be powered from the DC supply which feeds the throttle to which it is connected, and must "float" independently of everything else.

The SST/7: a second-generation solid-state throttle

Part 1

Perhaps "cab simulator" would more accurately describe this throttle, since in addition to the expected momentum effects coupled to both brake and throttle responses, this unit offers an air brake pressure gauge—a very important aid to enjoyable train control/**Don Fiehm**

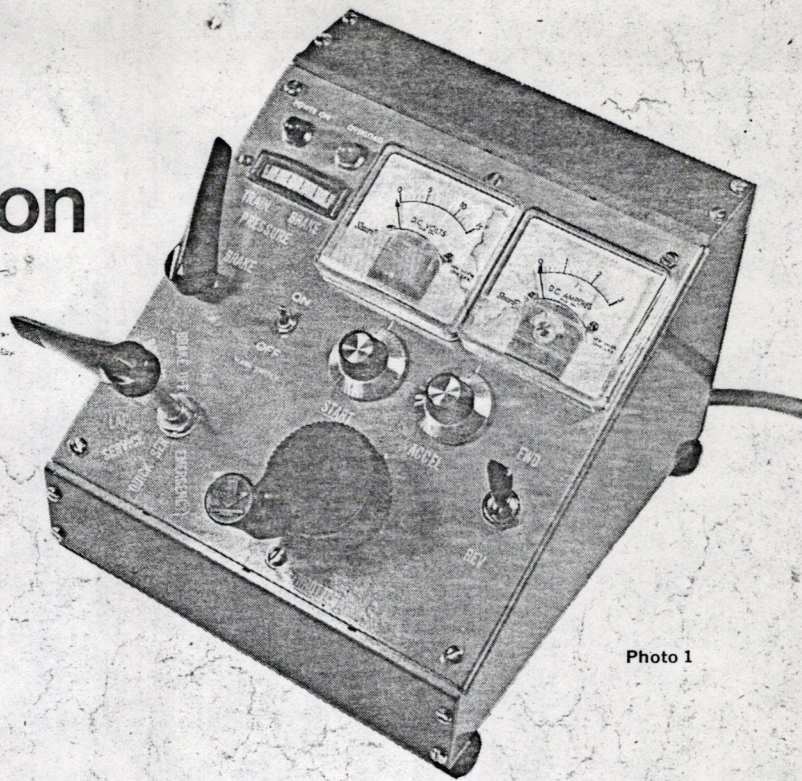


Photo 1

The "transistor throttle" has been in use on model railroads for over a decade. Time has brought about many advances in the semiconductor field, and a lot of changes have come in circuit design. The South Side Throttle (SST/7) incorporates many of the advances in both of these areas. The SST/7 is a complete package that gives the model railroader the feeling of being in the engineer's seat with tons of steel at his command.

History

It all began back in 1969 when a member of the South Side Switching & Sipping So-

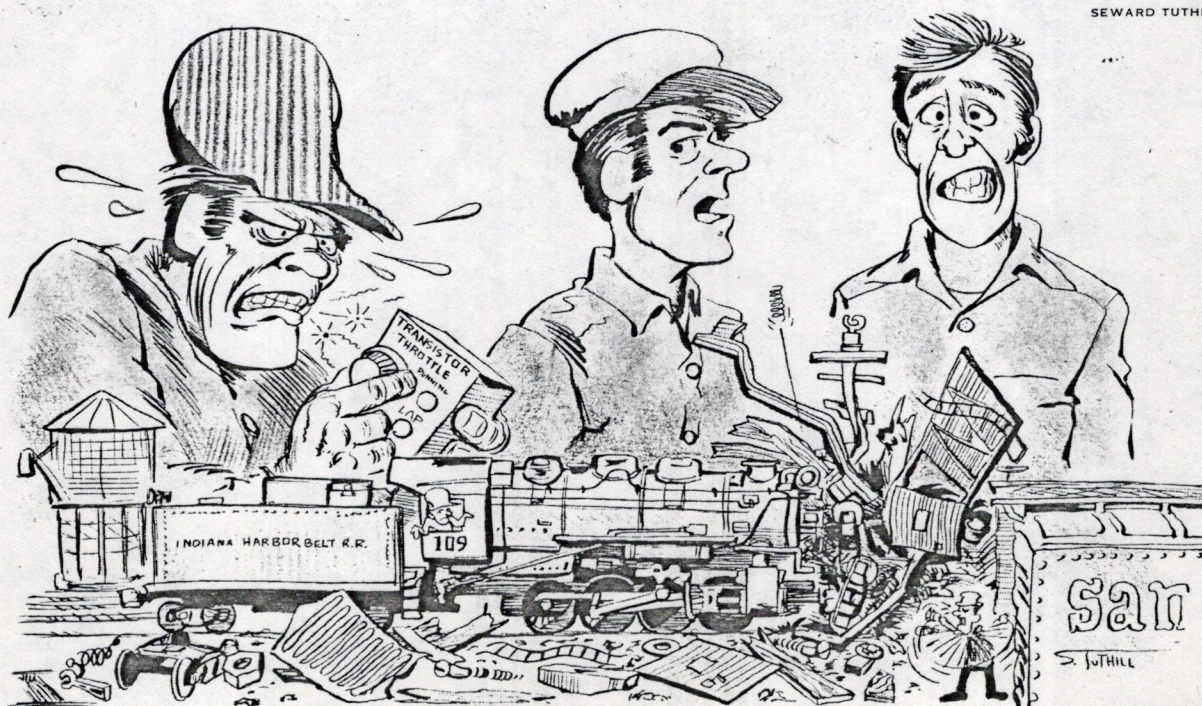
ciety in San Jose, Cal., suggested that we build a solid-state throttle as a club project. The club already had a number of different "transistor throttles" in use that were designed by one of the club members. It was decided to use the best of the existing ideas and, from there, design a new generation of solid-state throttles.

About four years were spent on research and development before everyone was satisfied with the circuit design. Development was aided by having members run a real loco for "feel" and having real railroad employees operate the "breadboard" model of the throttle. Research was

checked by simulation in an IBM 360/195 computer.

A model railroad friend, who works for the Southern Pacific, is responsible for the addition of the independent brake and the ability to "work steam" (work the brake and throttle together). The brake pressure meter came to be when a VOM (volt-ohm meter) was connected to the output of the brake pressure op-amp for test purposes. As one member put it, "The brake rate meter is more useful to me than either the volt or amp meter."

The throttle was tested mainly with HO equipment, but tests were also run with an



SEWARD TUTHILL

"Yeh, well, Bob ain't got the feel of his new momentum throttle yet, and he's re-kitted a couple o' wood boxcars..."

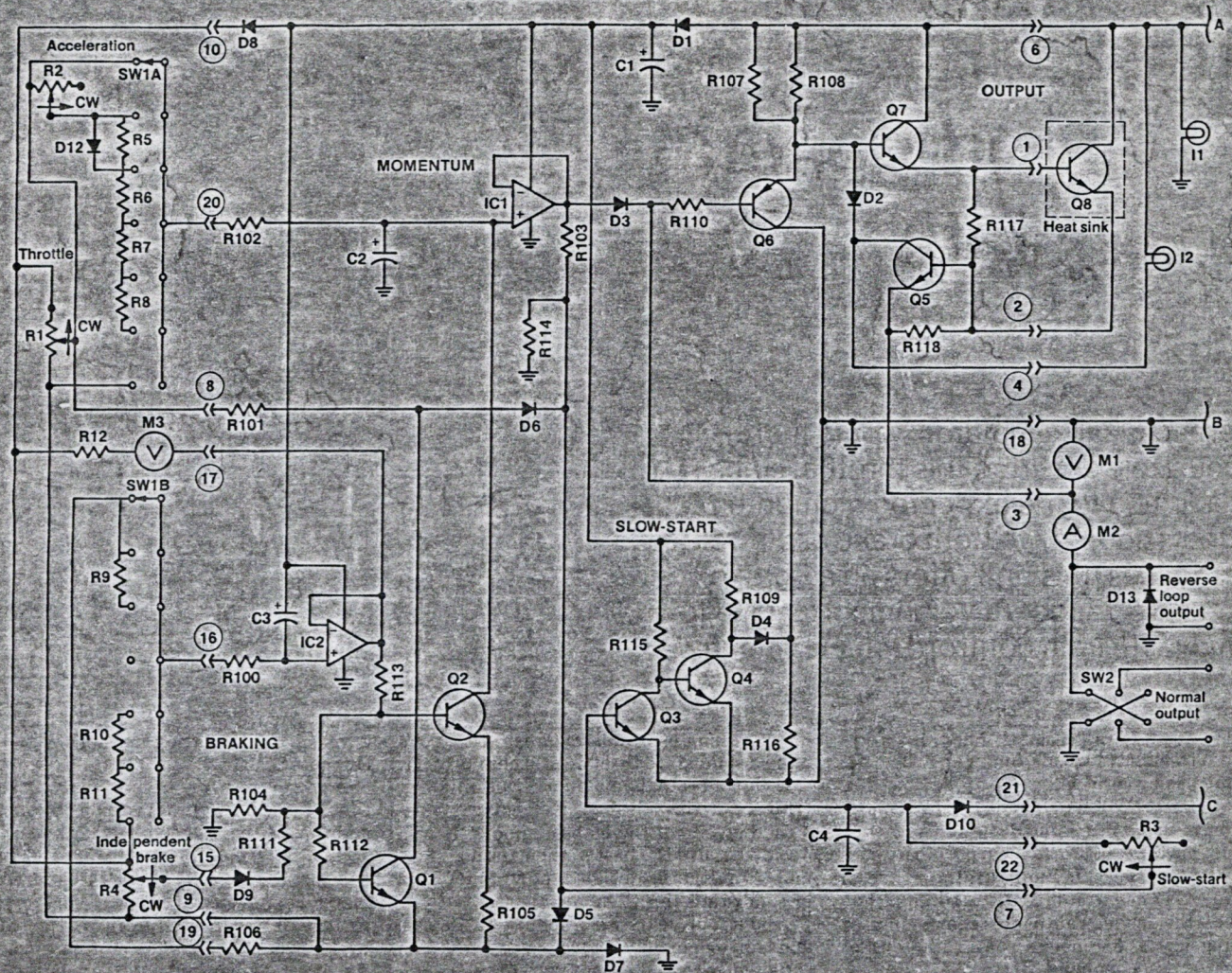
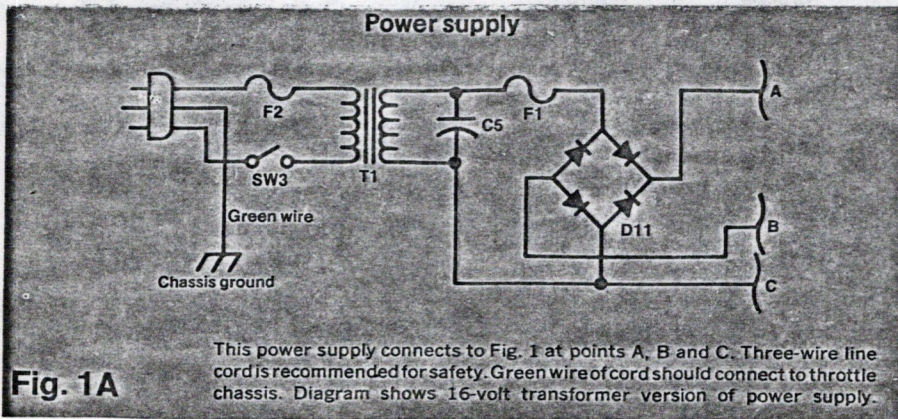


Fig. 1 Complete diagram of SST/7 shows circuits that are on printed circuit card in center section of diagram. Numbers inside circles are printed circuit card connector pin numbers. Points A, B and C connect to power supply shown in Fig. 1A.



This power supply connects to Fig. 1 at points A, B and C. Three-wire line cord is recommended for safety. Green wire of cord should connect to throttle chassis. Diagram shows 16-volt transformer version of power supply.

Fig. 1A

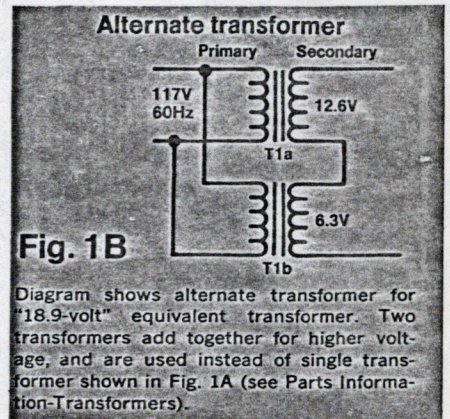


Fig. 1B

Diagram shows alternate transformer for "18.9-volt" equivalent transformer. Two transformers add together for higher voltage, and are used instead of single transformer shown in Fig. 1A (see Parts Information-Transformers).

O scale SP 4-8-2 pulling six lighted passenger cars. The throttle design worked equally well in both scales and should work well in any scale that does not require more than two amps, which is admittedly marginal for many O scale locomotives.

Research, development and testing the basic design led to the following improvements that were included in the finalized version:

1. minimum number of adjustments
2. electronic overload protection
3. true prototype braking action with brake air pressure gauge

4. printed circuit card for most electronic components

5. use of silicon semiconductors
6. use of integrated circuits (741 op-amps)

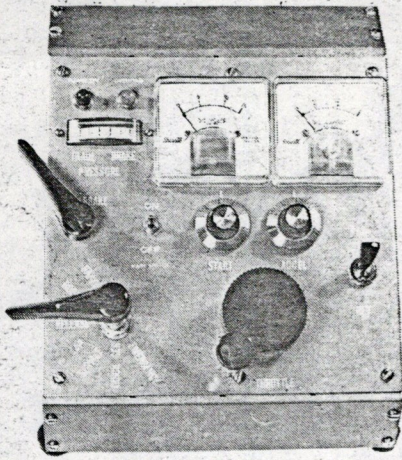
The name "throttle" was almost changed to "cab simulator" because it performs so many more functions than found in most other transistor throttles.

Building the throttle

Since we were designing one common set of electronics for all members' throttles, it was decided to put the circuit on a

printed circuit (PC) card. For ease of maintenance, we used a 22-pin connector so the card could be swapped should trouble occur in a unit.

Six of the seven club members agreed to use the Marnold single-size cabinet (available from Wm K. Walthers, Inc) to house their throttles. The seventh member decided to build his from standard electronic metal boxes. The layout of components on the front of the Marnold panels started with six people and six different "ideal" ways to lay it out. We ended up combining many of the good ideas and laid out one



Circuit description of the SST/7

The throttle is broken down into six sections in the following description and each section is covered in detail

A: Power Supply

A conventional bridge rectifier (D11) converts the output of a 16V-transformer from a.c. to pulsating d.c. Diode (D1) and capacitor (C1) takes the pulsating d.c. and filters it for the 20-volts d.c. used to power the control section of the throttle. A.c. is tapped off the bridge rectifier for use in the slow-start circuit. The a.c. is used to discharge capacitor C4 at a 60 Hz rate (see Section D). Fuse F1 is used for protection against a fault in the circuit and should not blow even when the output of the throttle is shorted. Fuse F2 is used to protect the unit from transformer shorts.

B: Throttle and Acceleration Control

The throttle pot (R1) is connected in series with diodes D8 and D7. These forward-conducting diodes provide a 0.7-volt drop each to limit the voltage output to prevent overloading op-amp IC1 at the extreme settings of R1. The output of R1 is to feed to the function brake switch SW1, the slow-start circuit and acceleration control R2.

The function brake switch SW1 has two sections. The first section (SW1A) controls the acceleration, and the second (SW1B) controls the braking. In the first position of SW1 (brake off), the output of the throttle is fed directly to the op-amp, thereby operating in a "direct" mode. Position 2 (booster) of this switch feeds the op-amp through acceleration control R2. In this switch position, the voltage will rise and fall slowly. The time of rise and fall is determined by the setting of acceleration control R2. Position 3 (release) puts parallel diode D12 and a 1 meg resistor in series with the acceleration control. This modifies the effect of the throttle so that when the throttle is opened up (increase speed) the action will be the same as it was in position 2; but when you close the throttle (decrease speed) the train will "coast" and slow down very slowly. This same mode of operation holds true for the remaining position of SW1 except for Emergency. The braking positions of the switch will, of course, slow the train at a faster rate. (See the section on Braking Controls for more information.) The output of the throttle also goes to the slow-start circuit so the circuit can sense when the throttle is open.

C: Braking Controls

The train line brake control is incorporated into the function brake switch (SW1). The second section (SW1B) of this switch controls the charge and discharge of capacitor C3. The voltage on capacitor C3 is used to determine brake rate of the throttle the same as the air pressure in a train line determines a train brake rate. In the second position (booster), capacitor C3 is charged at a faster rate than when in the third position (release). Charging this capacitor releases the "brakes." (Note in the circuit diagram that capacitor C3 has its plus terminal connected to 20 volts and when charged the minus terminal is at a near ground voltage.) In the fourth position the capacitor is left at whatever charge it had when the switch was moved to this position. In the fifth position (service) capacitor C3 is discharged. Position six (quick service) discharges at a faster rate. Position seven (emergency) is a very fast discharge rate.

Op-amp IC2 operates in a voltage-follower configuration to prevent loading capacitor C3. In this configuration, the input impedance into the op-amp is 400 meg ohms! The train line brake pressure meter (M3) reads the voltage of the capacitor via the op-amp. The meter has its plus terminal connected to the plus 20-volt control voltage, so the me-

ter will read maximum voltage of about 9 volts when the brakes are fully released. The air brake gauge in a locomotive typically reads about 90 psi when the train line is fully charged. Note that a 0-10 volt meter is used, but a dropping resistor (R12) changes this to read 0-20V. The output of the brake op-amp is fed into a two-transistor circuit that controls slow-start (Q1) and brake rate (Q2). When the brakes are released, both of these transistors are off. When the brakes are applied, Q1 turns "on" to signal the slow-start circuit that the brakes have been applied. Q2 then allows a current to flow from the momentum capacitor (C2). The rate of flow from the momentum capacitor depends on the voltage of the train line brake capacitor (C3). The resistor (R105) in the emitter leg of transistor Q2 forms a constant-current circuit. This means that once a brake rate is set, the train will slow at a constant rate. The independent brake is designed to operate like a self-lap brake. In the off position this brake has no effect. As the independent brakes are applied, a voltage is put into the same point as the train line brake; both brakes can be used at the same time (diode D9 isolates the independent brake when it is off). The independent brake handle should be limited to about 120 degrees of rotation. Further rotation may cause the minimum output voltage of the throttle to increase.

D: Slow-start Circuit

The slow-start circuit is turned on and off from three different sources: (1) the throttle; (2) brake control; and (3) op-amp IC1 (momentum control). The 10K (R101) resistor from the throttle is used to turn the slow-start circuit on when the throttle is opened. The 10K (R103) resistor from the output of the momentum op-amp is used to keep the slow-start on until the output voltage from the throttle is at a minimum. This allows you to close the throttle at low speed and have the slow-start circuit continue until the loco stops. Otherwise, closing the throttle at low speed would result in a quick change in speed due to the loss of the slow-start voltage. Transistor Q1 and diode D6 are used to turn the throttle input to the slow start circuit off when either of the brakes are applied. When the brakes are applied, the slow-start will continue to operate via the input from the momentum op-amp until the output reaches minimum.

The slow-start pulses are developed by the RC time constant of the slow-start control R3 and the slow-start capacitor C4 and diode D10. This circuit is fed by 60Hz (60 cycles per second) from the power supply. Because the 60Hz is picked up from one leg of the bridge rectifier, it goes plus for half of the cycle and goes minus 0.7 volts for the other half-cycle. During the minus part of the cycle, diode D10 conducts and discharges capacitor C4. When the 60Hz goes to the plus part of the cycle, capacitor C4 starts to charge via the 25K slow-start control (R3). When the charge reaches approximately plus 0.7 volts, transistor Q3 starts to conduct. This in turn causes transistor Q4 to stop conducting and allows the 1K resistor in the collector of Q4 to pull the output plus. Diodes D4 and D3 form an "or" circuit that drives this output circuit. The "pulse" from the slow start goes plus until the next minus part of the cycle discharges capacitor C4.

E: Output Circuit

The output circuits run on full-wave rectified voltage from the power supply instead of the filtered d.c. used for the control circuits. By operating the output stage on full-wave, which can draw as much as 2.5 to 3 amps, we eliminate the need for a large filter capacitor. Transistor Q6 is the only PNP transistor used in this throttle. It is operated as an emitter-follower with the collector connected to ground. When the output of the throttle is set to a minimum output, transistor Q6 draws its maximum current and holds resistor R107 and R108 (equal to 600 ohms) to near zero volts. As the output of the throttle is increased, the voltage of Q6's emitter will increase. Q6 effectively is a shunt that "robs" the current from the remaining output stage when the throttle is set for less than full output. The 1000 ohm resistor R110 in the base lead of Q6 is used to limit the base emitter current through this transistor when this junction is back-biased, as it would be when the output of the throttle is shorted. Transistors Q7 and Q8 are wired in a Darlington configuration and amplify the current available from the resistors R107 and R108.

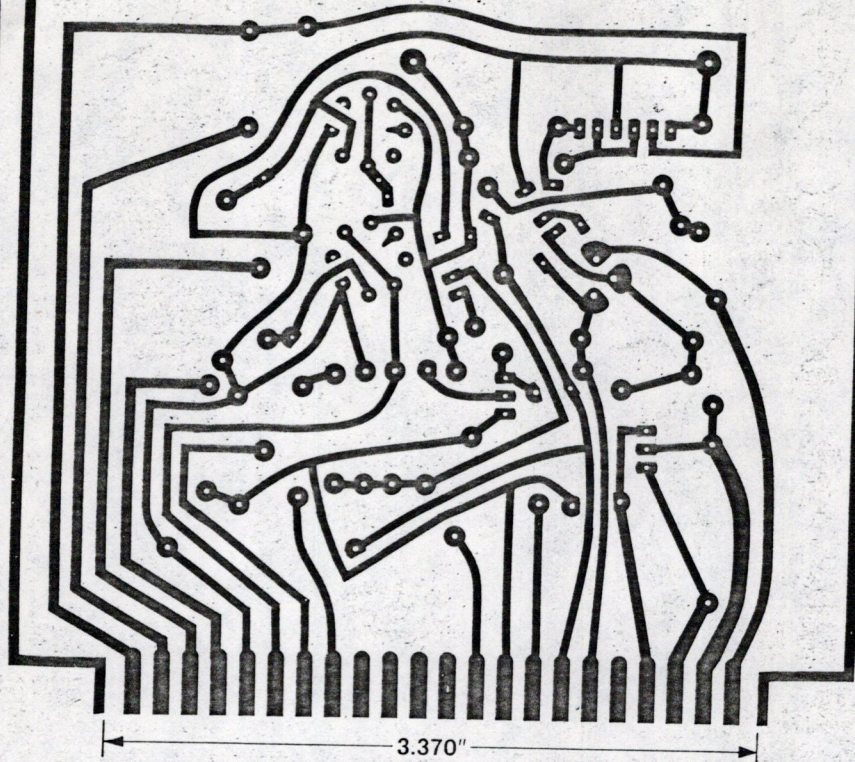
F: Overload Circuit

The 0.27 ohm resistor in the emitter leg of the output transistor Q8 is used to sense the output current of the throttle. When the output current is great enough to produce a voltage drop of about 0.7V (at about 2.5 amps), transistor Q5 will turn on. The output of transistor Q5 does two things. First, it turns on the overload lamp; second, it draws current through resistors R107 and R108 (which feed the output circuit). The results of drawing current from these resistors is the output voltage goes down and the output current stays constant at approximately 2.5 amps. You can use an LED instead of the lamp for overload indication but be sure you put in a current limiting resistor in series with the LED. If you use a different lamp than the one shown in the parts list, be sure it does not draw more than 70 milliamps (.070 amps) or you may overheat transistor Q5. You can omit the lamp and the circuit will still function properly.

Diode D13 protects the throttle from shorts from other power pack or throttles that are of the opposite polarity.

SST-7

PF



This artwork is for printed circuit card. Pin 1 is on right side of this view. Final card should be cut just inside the strip that runs around the card and along bottom of contact fingers. Be sure card matches dimension so that it will fit connector. Card should be from .054" to .071" thick for same reason.

Fig. 2

SST/7 parts list

- 1: Front panel and cabinet parts
- Front panel—Full Panel Plain (Marnold M509)
- Cabinet—Single Cabinet (Marnold M551)
- Decals—Transistor Panel White Decals (Walthers pack #D543W)
- I1: Power-on indicator—18 volt green (Walthers #E400G or equivalent)
- I2: Overload indicator—18 volt red (Walthers #E400R or equivalent, see text)
- M1: 0 to 15 volt d.c. meter (Shurite #8108)
- M2: 0 to 3 amp d.c. meter (Shurite #8202)
- M3: 0 to 10 volts d.c. meter (Shurite #3107 edgewise model)
- R1: 1K ohm potentiometer linear taper (throttle)
- R2: 1 Meg ohm potentiometer linear taper (acceleration)
- R3: 25K ohm potentiometer linear taper (slow-start)
- R4: 10K ohm potentiometer linear taper (independent brake)
- (All resistors ½ watt 10% unless otherwise noted. K=1000; Meg=1,000,000.)
- R5: 1 Meg ohms
- R6: 5.6K ohms
- R7: 10K ohms
- R8: 33K ohms
- R9: 33K ohms
- R10: 68K ohms
- R11: 22K ohms
- R12: (a) 2.4K ohms, ½ watt with 16-volt transformer (Fig. 1a; see text). (b) 3.3K ohms, ½ watt with 18.9-volt transformer (Fig. 1b; see text).
- D12: 1 amp, 50-volt diode (Radio Shack 276-1101, 1N4001 or equivalent)
- SW1: 2 pole, 12 position rotary switch (Centralab PA 2005 or equivalent). Note: Only 7 positions of this switch are used
- SW2: 2 pole double throw (DPDT) toggle switch (Radio Shack 275-652 or equivalent)
- SW3: Single pole single throw (SPST) toggle switch (Radio Shack 275-603 or equivalent)
- Knobs—Throttle—(Model Rectifier Corp., Throttle Master Knob—Walthers #K-1); brake—independent (Waldom #WA2100A); brake—train line (Waldom #WA2100A); Slow-start and acceleration (Radio Shack 274-413; part no. includes 2 knobs).
- 2: Back panel parts
- C5: .01 uf disk ceramic capacitor, 100 volt or better rating.
- D11: Bridge rectifier 6 amp, 50 volt (Radio Shack 276-1146 or equivalent)
- D13: 3 amp, 50 volt diode (Radio Shack 276-1141 or equivalent)
- F1: 3 amp glass fuse (Buss 3AG3A, Radio Shack 270-1276 or equivalent)
- F2: 1 amp glass fuse (Buss 3AG1A, Radio Shack 270-1273 or equivalent)
- Q5: 2N3055
- T1: 16-volt, 2.5-amp transformer for Fig. 1a (TAB #TR9000RM)
- For Alternate Transformer arrangement use the following two transformers instead of T1:
- T1a: 12.6-volt, 3-amp transformer for Fig. 1b (Radio Shack 273-1511)
- T1b: 6.3-volt, 3-amp transformer for Fig. 1b (Radio Shack 273-1510)
- Heat sink: (Motorola MS-10 or equivalent)
- Transistor mounting kit: (Motorola MK-15 or equivalent. Note: mounting kit MK-15 included with heat sink MS-10)
- Connector for printed circuit card: 22 pins on 0.156" centers (Cinch 50-22A-20, Amphenol 143-022-01 or equivalent)
- Connector: Binding post, 4 required (Walthers E403, two per package, or equivalent)
- Fuse holders: F1—Clip-in fuse holder (Radio Shack 270-739 or equivalent); F2—In-line fuse holder (Radio Shack 270-1281 or equivalent)
- Miscellaneous: Line cord, silicon grease, wire, mounting hardware, etc.
- 3: Printed circuit card parts
- C1: 250 uf, 25 volt or greater, electrolytic capacitor (Radio Shack 272-1017 or equivalent; note 1)

79

7-122

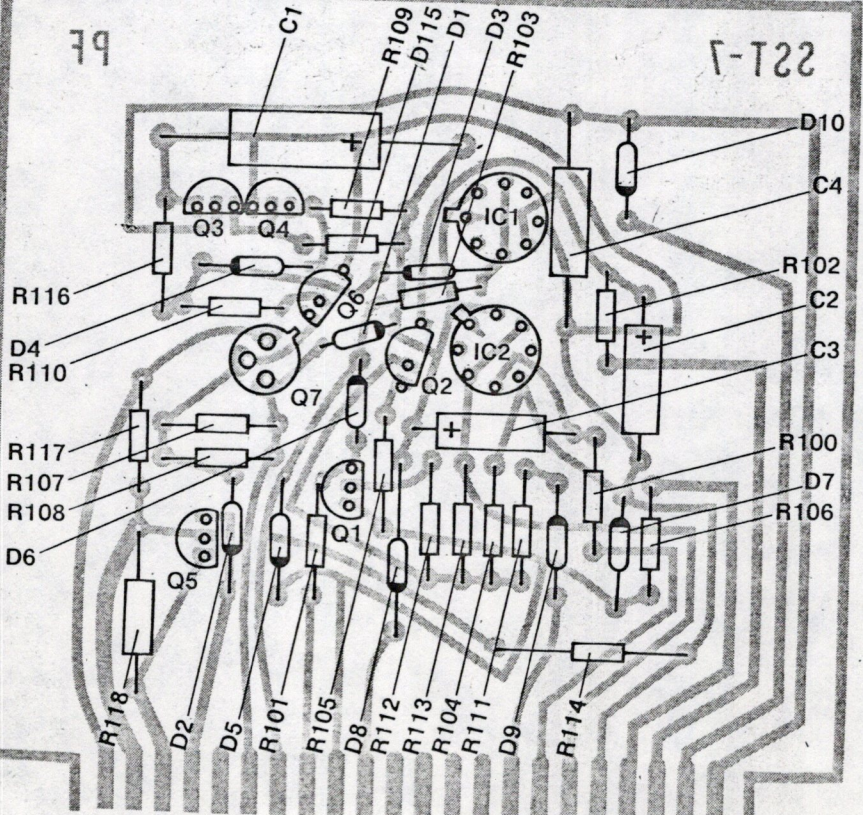
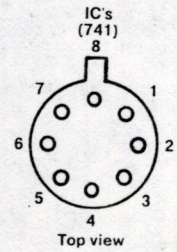
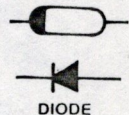


Fig. 3

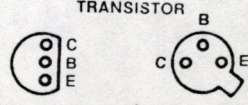
Placement of components on printed circuit cards is shown, with PC card indicated as an "X-ray" view (as though seen by actually looking through the card), as components are located on opposite side from current paths.



Top view



DIODE



TRANSISTOR

Top view

Fig. 3A

C2, C3: 50 uf, 25 volt or greater, electrolytic capacitor (Radio Shack 272-1015 or equivalent; note 1)
 C4: 0.47 uf, 100 volt or greater, tubular capacitor (Radio Shack 272-1054 or equivalent; note 1)
 D1 through D10: 1 amp, 50 volt silicon diode, 1N4001 (Radio Shack 276-1101 or equivalent; note 1)
 IC1, IC2: 741 op amp, TO-5 case for p.c. card (Radio Shack 276-010 or equivalent)
 Q1, Q2, Q3, Q4, Q5: Silicon transistor, MPS 2923 (Motorola number)
 Q6: Silicon transistor, MPS 6517 (Motorola number)
 Q7: 2N3053
 (All resistors: 1/2-watt 10% unless otherwise noted; K=1000)

R100 through R106: 10K ohms
 R107, R108: 1.2K ohms
 R109, R110: 1.0K ohms
 R111: 7.5K ohms
 R112: 2.4K ohms
 R113: 24K ohms
 R114: 3.6K ohms
 R115: 20K ohms
 R116: 5.1K ohms
 R117: 100 ohms
 R118: 0.27 ohms, 5%, 2 watts

Printed circuit card: Make from artwork in the article or purchase (see note 2).

Note 1: If you are using the printed circuit card be sure that the "equivalent" parts you obtain will fit in the area allowed for them on the card.

Note 2: In cooperation with the author, an etched and drilled printed circuit card for the SST/7 is available from Gold Spike Lab, P.O. Box 24772, San Jose, CA 95154. Cost of the card is \$8.95 (includes postage and handling for U.S.A. only); California residents must add sales tax. Allow four to six weeks for delivery.

Parts information

TRANSFORMERS: If you do not have a 16-volt transformer, the 18.9-volt transformer made from two separate transformers (T1a and T1b) will work just as well. If you use diode constant lighting in your locos, the two transformers will give you a little more voltage output from the SST/7 at maximum throttle setting to help run your locos a little faster. To connect the two transformers (see Fig. 1b), connect the input (117-volt primary) windings in parallel and the output (secondary) windings in series. You have a 50-50 chance of getting output of the transformers out of phase when you wire them. When you turn power on, check the d.c. voltage out of the bridge rectifier. If the voltage is less than 10 volts, reverse the wires from the secondary of one of the transformers. Fuse F2 should be installed if the transformers used are not UL approved. Be sure to use the in-line fuse holder on this fuse because it is connected to 117 volts!

SEMICONDUCTORS: Watch out for those "25 for \$1" bargain basement-type semiconductors. Many times, in the fine print, you will notice that the parts are "untested." The "fall out" from these types of parts is normally so bad that you are better off buying good reliable parts to start with.

TRANSISTORS: The transistors with the "MPS XXXX" numbers (Q1 through Q6) are Motorola house number parts. If you wish to use a substitute here are the general characteristics.

MPS 2923—General Purpose NPN Silicon Transistor: gain, (hfe) 90 to 180; max voltage, (Vcb) 25 volts d.c.; max current, (Ic) 100 milliamps; max power dissipation, 200 milliwatts.

MPS 6517—General Purpose PNP Silicon Transistor: All other specifications are the same as the MPS 2923

RESISTOR R12: The values in the parts list for R12 will cause the brake meter to read about 9 volts in most cases. But, due to variation in line voltage in your area and tolerance in the manufacturing of the transformer(s), the brake meter may not read 9 volts when the train line brakes are released. If it is too far off you can change the value of R12 to get the meter to read closer to 9 volts. Increasing the value of this resistor will lower the meter reading and vice versa.

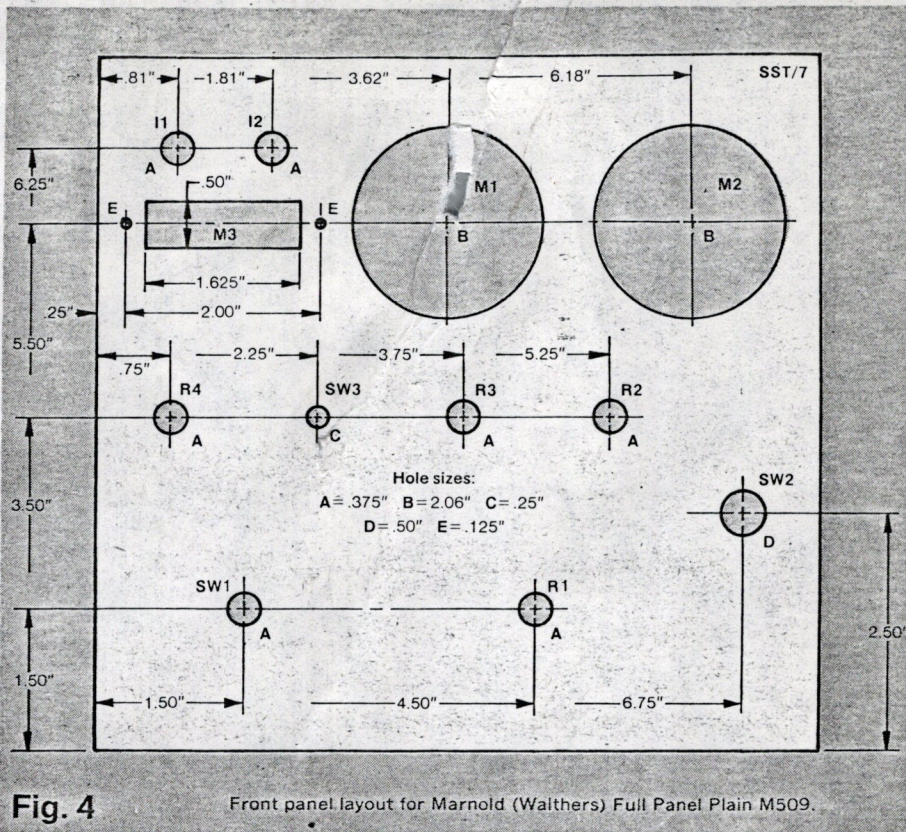


Fig. 4

Front panel layout for Marnold (Walthers) Full Panel Plain M509.

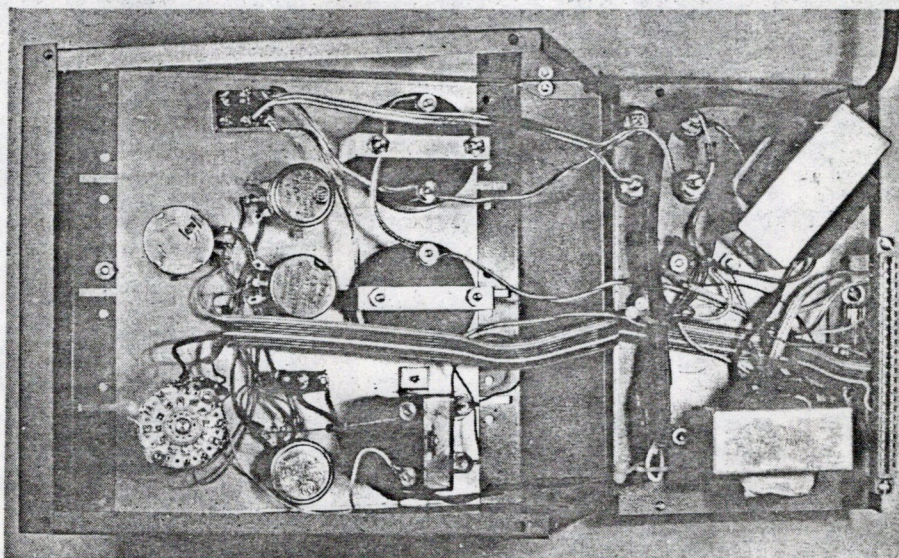


Photo 2:

Two-transformer version of SST/7 is shown open for wiring with components spread out to ease task.

standard panel (photo 1). The back panel ended up with one standard layout and one variation for the use of two transformers instead of one (photo 2).

The following is a description of the steps the club members went through in assembling their throttles:

The mounting holes were punched into the front panel. Then the panels were decaled with the decals furnished with the panels plus Walthers' decal set for transistor throttles #D543W. Clear-gloss spray lacquer was applied over the decals, and then all of the parts were mounted on the front panel. Fig. 4 shows the layout of the holes punched in the front panel.

All of the parts for the back panel were put into place to determine the best loca-

tion without interfering with the parts on the front panel (photo 2). The panel was then drilled, the parts were installed and the throttles case was temporarily assembled for visual inspection. Note: When you mount the 2N3053 transistor (Q8) on the heat sink, be sure to use the insulating mounting kit and use silicon grease on both sides of the insulating washer.

If you build your SST/7 with a PC card, use standard precautions when soldering and when working with the semiconductors (diodes, transistors and IC's—integrated circuits). Soldering should be done with a small soldering iron rated at 25-40 watts and should be left on only long enough to melt the solder. Semiconductors should be heat-sunk when soldering.

This can be done by holding the lead to be soldered at a point between the component and the solder joint with a pair of needle nose pliers when the heat is applied to the joint. Fig. 3 shows the location of the components on the PC card.

PC cards can be made from the artwork provided with the article (Fig. 2), or you can wire a piece of a pre-punched circuit board and connect it into the throttle without using the 22-pin connector. We built one card to prove that the artwork was correct, then made the necessary corrections to the artwork. We built the remaining cards using the breadboard throttle to test the cards.

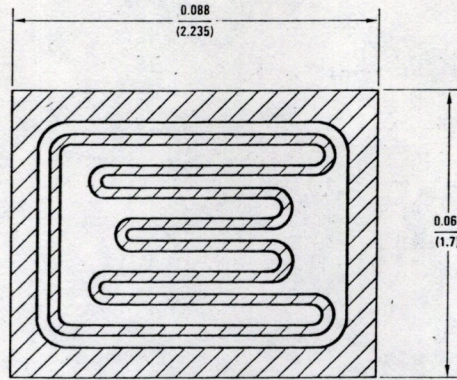
Next month we'll get into the actual wiring, checkout and usage of the SST/7. ☐



POWER (Continued)

Type No.	Case Style	V _{CEO} (V) Min	V _{CEO} (V) Min	V _{EB0} (V) Min	I _{CEX} [†] I _{CEB} (μA) Max	V _{CB} (V)	I _{CE} & V _{CE} (A) (V)	V _{ESAT} (V) Max	V _{ESAT} (V) Min	I _C (A)	C _{ob} (pF) Max	f _T (MHz) Min	f _T (MHz) Max	I _C (A)	Process No.
2N5190	TO-126		40		100	40	25 100 1.5 2	0.6 1.4		1.5 4		2		1	4E
2N5191	TO-126		60		100	60	25 100 1.5 2	0.6 1.4		1.5 4		2		1	4E
2N5192	TO-126		80		100	80	20 80 1.5 2	0.6 1.4		1.5 4		2		1	4E
2N5294	TO-220		70		500 [†]	50 (100Ω)	30 120 0.5 4	1		0.5		2		0.2	4E
2N5296	TO-220		40		100	35	30 120 1 4	1.0		1		2		0.2	4E
2N5298	TO-220		60		500 [†]	50 (100Ω)	20 80 1.5 1	1.0		1.5		2		0.2	4E
2N5490	TO-220		40		5 mA*	55	20 100 2 4	2.0		0.5					4E
2N5492	TO-220		55		1 mA*	70	20 100 2.5 4	2.0		0.2					4E
2N5494	TO-220		40		1 mA*	55	20 100 3 4	2.0		0.5					4E
2N5496	TO-220		70		1 mA*	85	20 100 3.5 4	2.0		7					4E
2N6121	TO-220		45		100	45	25 100 1.5 2	0.6 1.4		1.5 4		2.5		1	4E
2N6122	TO-220		60		100	60	25 100 1.5 2	0.6 1.4		1.5 4		2.5		1	4E
2N6123	TO-220		80		100	80	20 80 1.5 2	0.6 1.4		1.5 4		2.5		1	4E
2N6129	TO-220		40		100	40	20 100 2.5 4	1.4		7					4E
2N6130	TO-220		60		100	60	20 100 2.5 4	1.4		7					4E
2N6131	TO-220		80		100	80	20 100 2.5 4	2.0		7					4E
2N6288	TO-220		30		100*	37.5	30 150 3 4	1.0 2.0		3 6.5	250	4		0.5	4E
2N6290	TO-220		50		100*	56	30 150 3 4	1.0 2.0		2.5 6.5	250	4		0.5	4E
2N6292	TO-220		70		100*	75	30 150 2 4	1.0 2.0		2 6.5	250	4		0.5	4E

NPN Transistors



DESCRIPTION

Process 4E is a double epitaxial silicon mesa device with diffused emitter. Complement to Process 5E.

APPLICATION

This device was designed for general purpose power amplifier and switching circuits where a large safe operating area is required.

PRINCIPAL DEVICE TYPES

- TO-220, BCE: 2N5294, 96, 98
2N5490, 92, 94, 96
2N6121-23
2N6129-31
2N6288, 90, 92
- TO-126, ECB: 2N5190-92

Parameter	Conditions	Min	Typ	Max	Units
BV_{CEO}	$I_C = 100 \text{ mA}$ (Note 1)	30		120	V
BV_{CBO}	$I_C = 1 \text{ mA}$	50			V
BV_{EBO}	$I_E = 1 \text{ mA}$	5	8		V
I_{CEO}	$V_{CE} = BV_{CEO} - 10V$			300	μA
I_{CBO}	$V_{CB} = BV_{CEO}$			100	μA
I_{EBO}	$V_{EB} = 5V$			1000	μA
h_{FE}	$I_C = 1.5A, V_{CE} = 2.0V$ (Note 1)	20		200	
$V_{CE(SAT)}$	$I_C = 4.0A, I_B = 0.4A$ (Note 1)			1.0	V
$V_{BE(ON)}$	$I_C = 4.0A, V_{CE} = 2.0V$ (Note 1)			1.3	V
f_t	$I_C = 0.5A, V_{CE} = 2V$	4			MHz
t_d	$I_C = 1.0A, I_{B1} = 0.1A, I_{B2} = 0.1A, V_{CC} = 30V$		0.10		μs
t_r	$I_C = 1.0A, I_{B1} = 0.1A, I_{B2} = 0.1A, V_{CC} = 30V$		0.25		μs
t_s	$I_C = 1.0A, I_{B1} = 0.1A, I_{B2} = 0.1A, V_{CC} = 30V$		0.35		μs
t_f	$I_C = 1.0A, I_{B1} = 0.1A, I_{B2} = 0.1A, V_{CC} = 30V$		0.23		μs
$P_{D(max)}$					
TO-220	$T_C = 25^\circ C$ $T_A = 25^\circ C$	50 2			W
TO-126	$T_C = 25^\circ C$ $T_A = 25^\circ C$	40 1.5			W
θ_{JC}					
TO-220	$T_C = 25^\circ C$			2.5	$^\circ C/W$
TO-126	$T_C = 25^\circ C$			3.12	$^\circ C/W$
θ_{JA}					
TO-220	$T_A = 25^\circ C$			62.5	$^\circ C/W$
TO-126	$T_A = 25^\circ C$			83.3	$^\circ C/W$
$T_{J(max)}$	All Plastic Parts	150			$^\circ C$

Note 1: Pulsed measurement = 300 μs pulse width.

axial silicon mesa device with
ent to Process 5E.

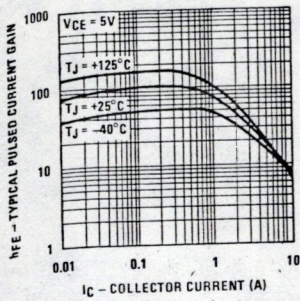
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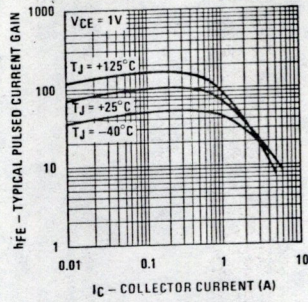
2

Max	Units
120	V
	V
	V
300	μ A
100	μ A
1000	μ A
200	V
1.0	V
1.3	MHz
	μ S
	μ S
	μ S
	W
	W
2.5	$^{\circ}$ C/W
3.12	$^{\circ}$ C/W
62.5	$^{\circ}$ C/W
83.3	$^{\circ}$ C/W
	$^{\circ}$ C

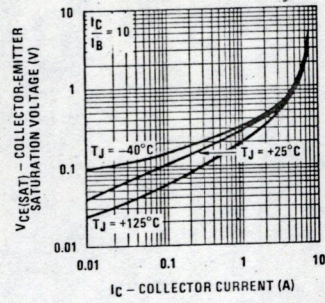
Typical Pulsed Current Gain vs Collector Current



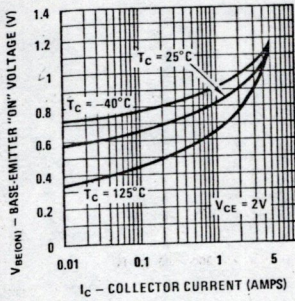
Typical Pulsed Current Gain vs Collector Current



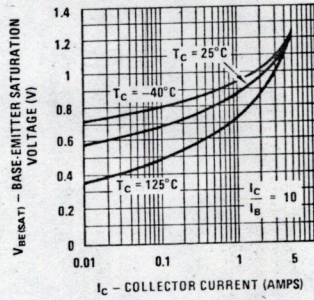
Collector-Emitter Saturation Voltage vs Collector Current



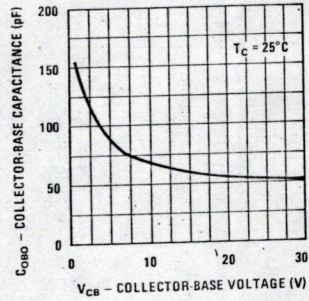
Base-Emitter ON Voltage vs Collector Current



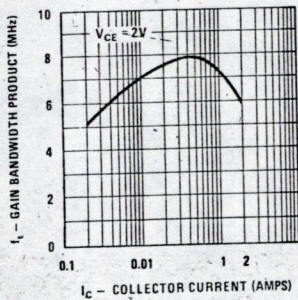
Base-Emitter Saturation Voltage vs Collector Current



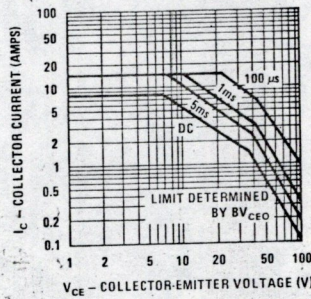
Typical Collector-Base Capacitance vs Collector-Base Voltage



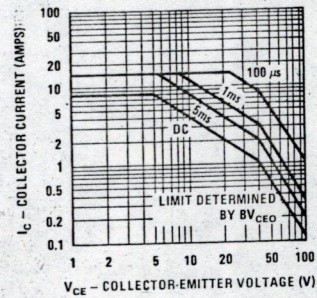
Gain Bandwidth Product vs Collector Current



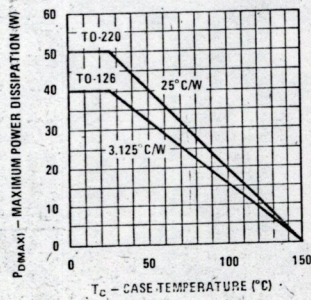
Safe Operating Area TO-220



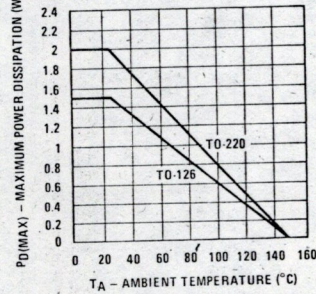
Safe Operating Area TO-126



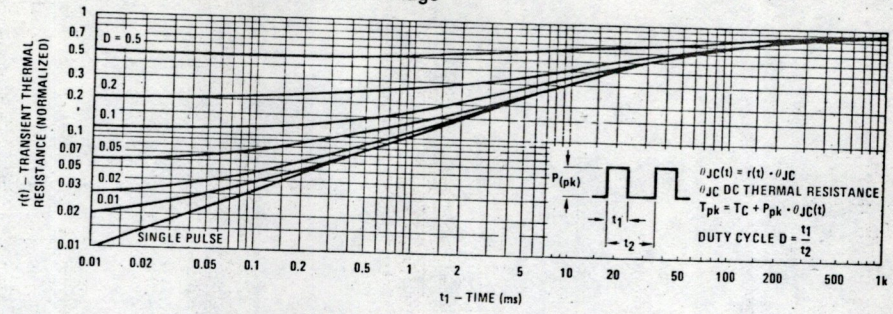
Maximum Power Dissipation vs Case Temperature



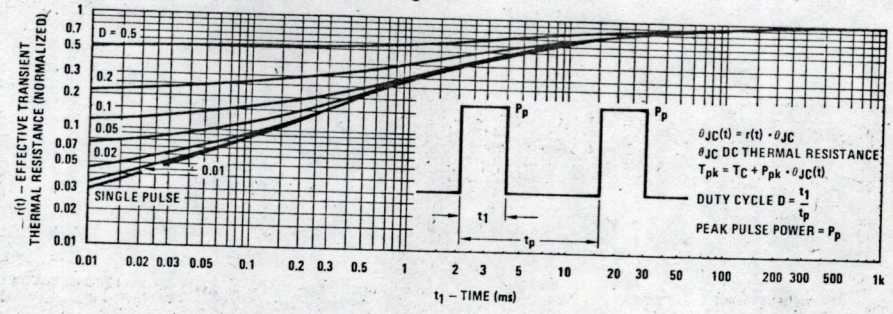
Maximum Power Dissipation vs Ambient Temperature



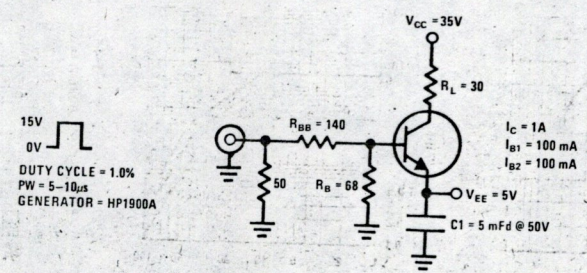
Thermal Response in TO-220 Package



Thermal Response in TO-126 Package



Switching Circuit





DARLINGTON (Continued)

Type No.	Case Style	V _{CEO} (V) Min	V _{CE0} (V) Min	V _{EB0} (V) Min	I _{CS} * I _{BO} (uA) Max	V _{CB} (V)	h _{FE} Min	h _{FE} Max	I _C (mA) @ V _{CE} (V)	V _{CE(SAT)} (V) Max	V _{BE(SAT)} (V) Min	V _{BE(SAT)} (V) Max	I _C (mA) @ V _{CE} (V)	C _{ob} (pF) Max	f _T (MHz) Min	f _T (MHz) Max	I _C (mA) @ V _{CE} (V)	Process No.
2N6037	TO-126		40		500	40	100	1500	4A 3 2A 3 0.5 3	2.0 3.0		4.0	2A 4A	200	25		0.75A	4J
2N6038	TO-126		60		500	60	100	1500	4A 3 2A 3 0.5 3	2.0 3.0		4.0	2A 4A	200	25		0.75A	4J
2N6039	TO-126		80		500	80	750	1500	4A 3 2A 3 0.5 3	2.0 3.0		4.0	2A 4A	200	25		0.75A	4J
2N6386	TO-220		40		300*	40	100	20,000	8 3 3 3	2.0 3.0			3 3	200	20		1	4J
MJE800	TO-126		60		200	60	750		1.5 3	2.5			1.5					4J
MJE801	TO-126		60		200	60	750		2 3	2.8			2					4J
MJE802	TO-126		80		200	80	750		1.5 3	2.5			1.5					4J
MJE803	TO-126		80		200	80	750		2 3	2.8			2					4J
TIP110	TO-220		60		1 mA	60	500		2 4	2.5			2					4J
TIP111	TO-220		80		1 mA	80	500		2 4	2.5			2					4J
TIP112	TO-220		100		1 mA	100	500		2 4	2.5			2					4J
TIP120	TO-220		60		200	60	1000		3 3	2.0			3 3					4J
TIP121	TO-220		80		200	80	1000		0.5 3	4.0			5 3					4J
TIP122	TO-220		100		200	100	1000		0.5 3	4.0			5 3					4J
2N6387	TO-220	60	60	5			1000	20,000	5 3 10 3	3.0		3.0	10 3	200				4K
2N6388	TO-220	80	80	5			1000	20,000	5 3 10 3	3.0		3.0	10 3	200				4K
2N6043	TO-220		60		500	60	10,000	20,000	4 4 8 4	2.0 4.0		4.5	4 4	200	4		3	4K
2N6044	TO-220		80		500	80	1000	20,000	4 4 8 4	2.0 4.0		4.5	4 4	200	4		3	4K
2N6045	TO-220		100		500	100	1000	20,000	4 4 8 4	2.0 4.0		4.5	4 4	200	4		3	4K
SE9300	TO-220		60	4			750 1000		1 3 4 3 7.5 3									4K

Transistors NPN

DESCRIPTION

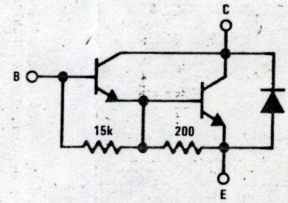
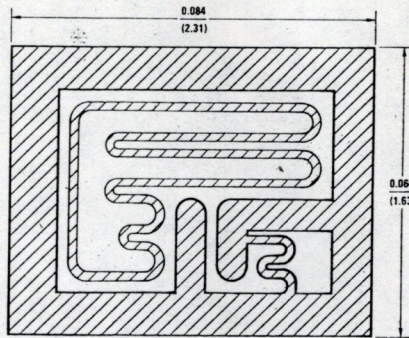
Process 4J is a double epitaxial silicon mesa device. Complement to Process 5J.

APPLICATION

This device was designed for use in driver and output stages of complementary audio amplifier circuits. It is also well suited for solenoid driver applications.

PRINCIPAL DEVICE TYPES

- TO-220, BCE: 2N6386
NSP2100-03
TIP110-12
- TO-126, ECB: 2N6037-39
MJE800-03



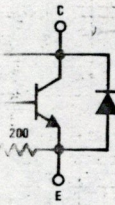
Parameter	Conditions	Min	Typ	Max	Units
BV_{CEO}	$I_C = 100 \text{ mA}$ (Note 1)	40		120	V
BV_{CBO}	$I_C = 100 \mu\text{A}$	70			V
BV_{EBO}	$I_E = 2 \text{ mA}$	5			V
I_{CEO}	$V_{CE} = 1/2 BV_{CEO}$			0.5	mA
I_{CBO}	$V_{CB} = BV_{CEO}$			20	μA
I_{EBO}	$V_{EB} = 5\text{V}$			2.0	mA
h_{FE}	$I_C = 2\text{A}, V_{CE} = 3\text{V}$ (Note 1)	750		20,000	
$V_{CE(SAT)}$	$I_C = 5\text{A}, I_B = 20 \text{ mA}$ (Note 1)			3.0	V
$V_{BE(ON)}$	$I_C = 5\text{A}, V_{CE} = 3\text{V}$ (Note 1)			2.5	V
C_{OBO}	$V_{CB} = 10\text{V}$		30		pF
$ h_{fe} $	$I_C = 1\text{A}, V_{CE} = 3\text{V}, f = 1 \text{ MHz}$		9		
t_{ON}	$I_C = 6\text{A}, V_{CE} = 30\text{V}$		1.25		μs
t_{OFF}	$I_C = 6\text{A}, V_{CE} = 30\text{V}$		2.75		μs
$P_{D(max)}$					
TO-220	$T_C = 25^\circ\text{C}$ $T_A = 25^\circ\text{C}$	50 2			W
TO-126	$T_C = 25^\circ\text{C}$ $T_A = 25^\circ\text{C}$	40 1.5			W
θ_{JC}					
TO-220	$T_C = 25^\circ\text{C}$			2.5	$^\circ\text{C/W}$
TO-126	$T_C = 25^\circ\text{C}$			3.12	$^\circ\text{C/W}$
θ_{JA}					
TO-220	$T_A = 25^\circ\text{C}$			62.5	$^\circ\text{C/W}$
TO-126	$T_A = 25^\circ\text{C}$			83.3	$^\circ\text{C/W}$
$T_{J(max)}$	All Plastic Parts	150			$^\circ\text{C}$

Note 1: Pulsed measurement = 300 μs pulse width.

Process 4J Power Darlington

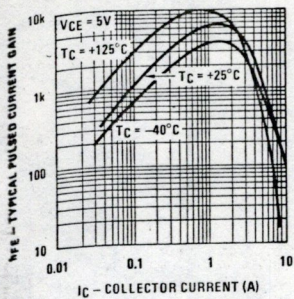
silicon mesa device. Com

for use in driver and output
audio amplifier circuits. It is
driver applications.

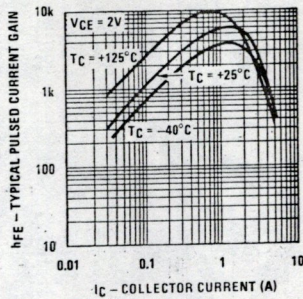


Max	Units
120	V
	V
	V
0.5	mA
	μ A
20,000	mA
3.0	V
2.5	V
	pF
	μ S
	μ S
	W
	W
2.5	$^{\circ}$ C/W
3.12	$^{\circ}$ C/W
62.5	$^{\circ}$ C/W
83.3	$^{\circ}$ C/W
	$^{\circ}$ C

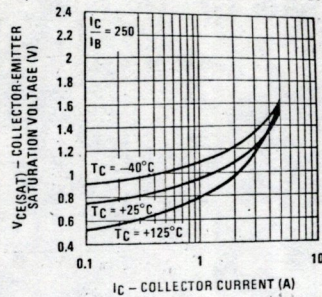
Typical Pulsed Current Gain vs Collector Current



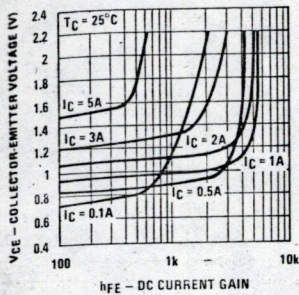
Typical Pulsed Current Gain vs Collector Current



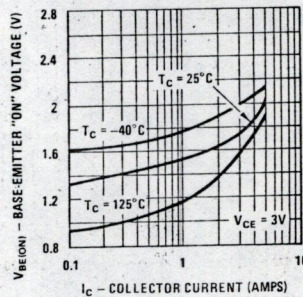
Collector-Emitter Saturation Voltage vs Collector Current



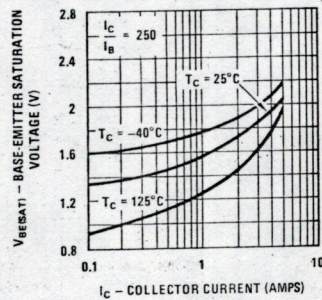
Collector Saturation Region—Typical Values



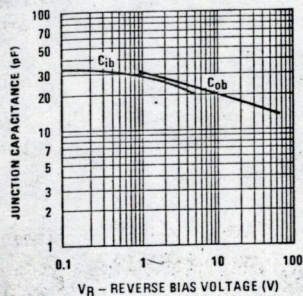
Base-Emitter ON Voltage vs Collector Current



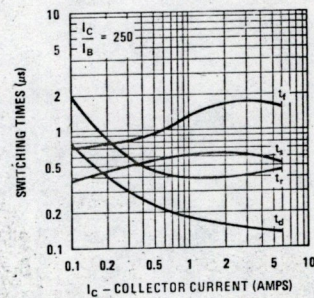
Base-Emitter Saturation Voltage vs Collector Current



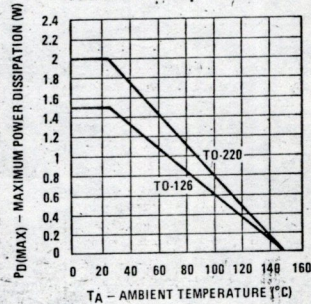
Junction Capacitance vs Reverse Bias Voltage



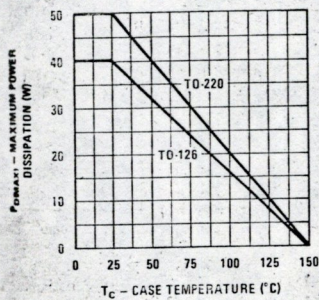
Switching Times vs Collector Current



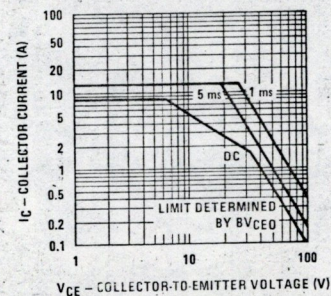
Maximum Power Dissipation vs Ambient Temperature



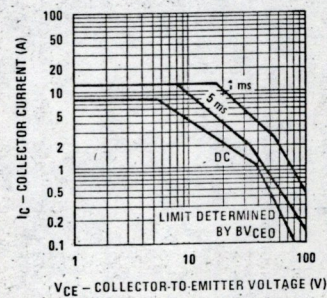
Maximum Power Dissipation vs Case Temperature



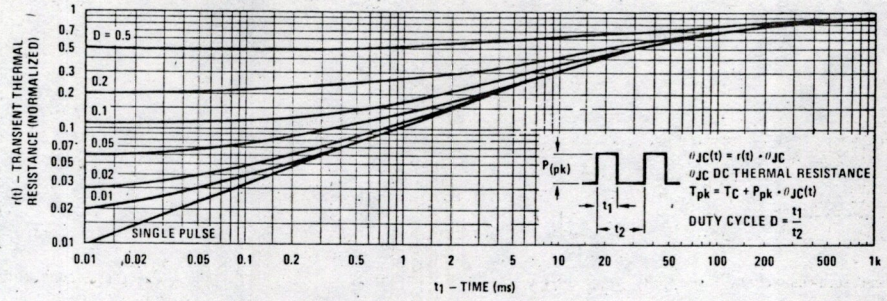
Safe Operating Area TO-220



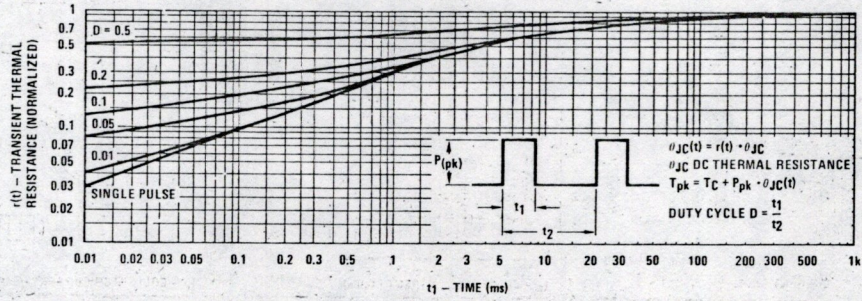
Safe Operating Area TO-126



Thermal Response in TO-220 Package



Thermal Response in TO-126 Package



Param
BV _{CEO}
BV _{CBO}
BV _{EBO}
I _{CEO}
I _{CBO}
I _{EBO}
h _{FE}
h _{FE}
V _{CE(SAT)}
V _{CE(SAT)}
V _{BE(SAT)}
V _{BE(ON)}
COBO
h _{fe}
P _{D(max)}
TO-2
theta _{JC}
TO-2
theta _{JA}
TO-2
T _{J(max)}

Note 1: Pulsed

DESCRIPTION

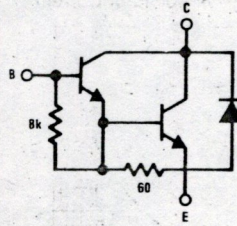
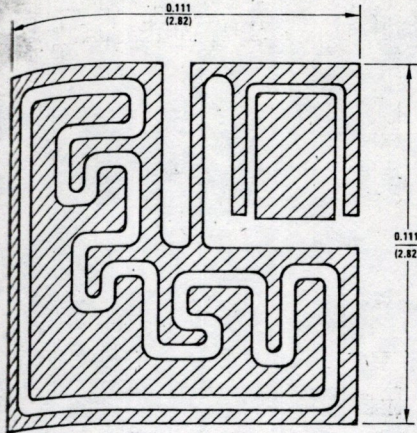
Process 4K is a double epitaxial silicon mesa Darlington transistor. Complement to Process 5K.

APPLICATION

The 4K was designed for general purpose amplifier and low-speed switching applications.

PRINCIPAL DEVICE TYPES

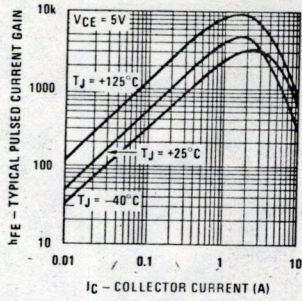
TO-220, BCE: SE9300-02
TIP121, 22
TIP130-32



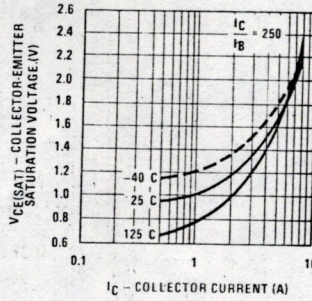
Parameter	Conditions	Min	Typ	Max	Units
BV_{CEO}	$I_C = 100 \text{ mA}$ (Note 1)	40		120	V
BV_{CBO}	$I_C = 200 \mu\text{A}$	70			V
BV_{EBO}	$I_E = 5 \text{ mA}$	5			V
I_{CEO}	$V_{CE} = 1/2 BV_{CEO}$			0.5	mA
I_{CBO}	$V_{CB} = BV_{CEO}$			100	μA
I_{EBO}	$V_{BE} = 5\text{V}$			2.0	mA
h_{FE}	$I_C = 4\text{A}, V_{CE} = 3\text{V}$ (Note 1)	750		18,000	
h_{FE}	$I_C = 8\text{A}, V_{CE} = 3\text{V}$ (Note 1)	100			
$V_{CE(SAT)}$	$I_C = 4\text{A}, I_B = 16 \text{ mA}$ (Note 1)			2	V
$V_{CE(SAT)}$	$I_C = 8\text{A}, I_B = 80 \text{ mA}$ (Note 1)			3	V
$V_{BE(SAT)}$	$I_C = 8\text{A}, I_B = 80 \text{ mA}$ (Note 1)			4	V
$V_{BE(ON)}$	$I_C = 4\text{A}, V_{CE} = 3\text{V}$ (Note 1)			2.8	V
C_{OBO}	$V_{CB} = 10\text{V}$			200	pF
$ h_{fe} $	$I_C = 3\text{A}, V_{CE} = 3\text{V}, f = 1 \text{ MHz}$	4			
$P_{D(max)}$					
TO-220	$T_C = 25^\circ\text{C}$	60			W
	$T_A = 25^\circ\text{C}$	2			
θ_{JC}					
TO-220	$T_C = 25^\circ\text{C}$			2.08	$^\circ\text{C/W}$
θ_{JA}					
TO-220	$T_A = 25^\circ\text{C}$			62.5	$^\circ\text{C/W}$
$T_{j(max)}$	All Plastic Parts	150			$^\circ\text{C}$

Note 1: Pulsed measurement = 300 μs pulse width.

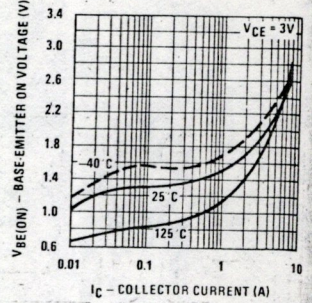
Typical Pulsed Current Gain vs Collector Current



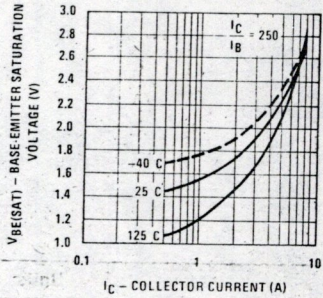
Collector-Emitter Saturation Voltage vs Collector Current



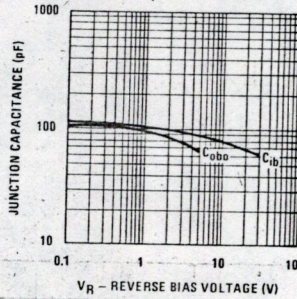
Base-Emitter ON Voltage vs Collector Current



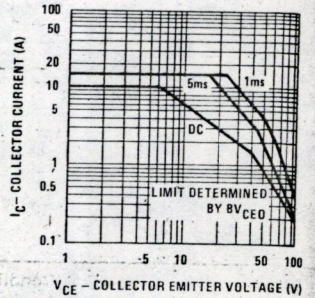
Base-Emitter Saturation Voltage vs Collector Current



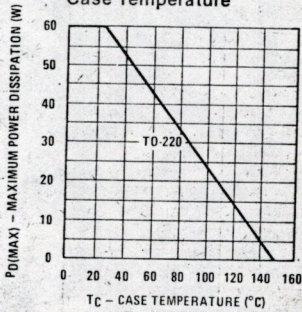
Junction Capacitance vs Reverse Bias Voltage



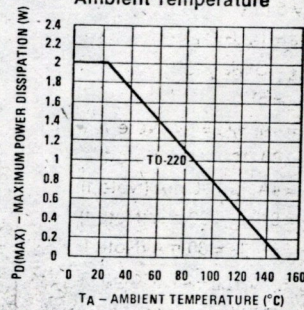
Safe Operating Area TO-220



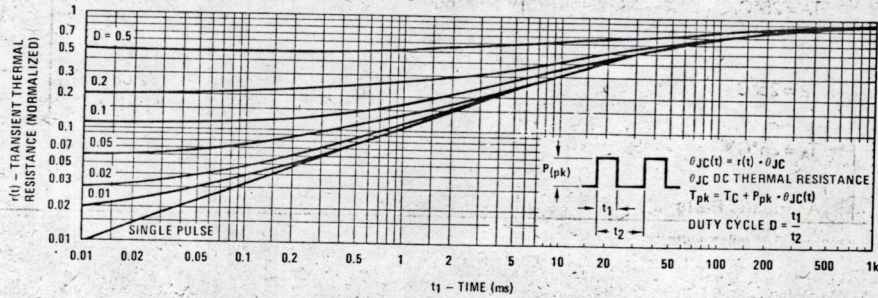
Maximum Power Dissipation vs Case Temperature



Maximum Power Dissipation vs Ambient Temperature



Thermal Response in TO-220 Package



Param
 BVCEO
 BVCES
 BVEBO
 ICES
 IEBO
 hFE
 hFE
 hFE
 hFE
 VCE(SAT)
 VBE(SAT)
 ft
 COB
 CIB
 tr
 ts
 tf
 PD(max)
 TO-2
 TO-12
 TO-20
 thetaJC
 TO-2
 TO-12
 TO-20
 thetaJA
 TO-2
 TO-20
 TO-12
 TJ(max)

Note 1: Pulsed



MEDIUM POWER (Continued)

Type No.	Case Style	V _{CEO} (V) Min	V _{CER} * (V) Min	V _{EB0} (V) Min	I _{CEO} (mA) Max	I _{CES} * @ V _{CB} (V) Min	h _{FE} Min	I _C & V _{CE} @ I _C & V _{CE} (mA) & (V) Min	V _{CE(SAT)} & V _{BE(SAT)} (V) & (V) Max	I _C @ I _C (mA) Min	C _{ob} (pF) Max	f _T (MHz) Min	t _{off} (ns) Max	NF (dB) Max	Test Conditions	Process No.	
2N2193A	TO-39	80	50	8	10	60	15	0.1	0.25	1.3	150	20	50	50		12	
2N2195	TO-39	45	25	5	100	30	10	1.0	0.35	1.3	150	20	50	50		12	
2N2195A	TO-39	45	25	5	100	30	10	1.0	0.25	1.3	150	20	50	50		12	
2N2243	TO-39	120	80	7	10	60	15	0.1	0.35	1.3	150	20	50	50		12	
2N2243A	TO-39	120	80	7	10	60	15	0.1	0.25	1.3	150	15	50	50		12	
2N2270	TO-39	60	45	7	50	60	30	1.0	0.2	1.1	150	12	100	50		12	
2N3019	TO-39	140	80	7	10	90	50	0.1	0.2	1.2	150	15	100	50		12	
2N3020	TO-39	140	80	7	10	90	30	0.1	0.2	1.1	150	12	80	50		12	
2N3053	TO-39	60	40	5	250	30	25	1.0	1.4	1.7	150	15	100	50		12	
2N3107	TO-39	100	60	7	10	60	35	0.1	0.25	1.1	150	20	70	1000		12	
2N3108	TO-39	100	60	7	10	60	40	0.1	1.0	2.0	1A	20	60	50	600		12

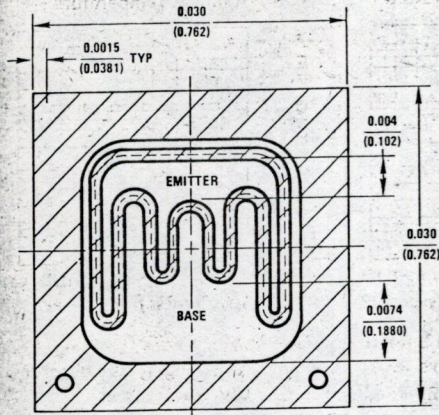
MEDIUM POWER (Continued)

Type No.	Case Style	V _{CEO} (V) Min	V _{CER} * (V) Min	V _{EB0} (V) Min	I _{CEO} (mA) Max	I _{CES} * @ V _{CB} (V) Min	h _{FE} Min	I _C & V _{CE} @ I _C & V _{CE} (mA) & (V) Min	V _{CE(SAT)} & V _{BE(SAT)} (V) & (V) Max	I _C @ I _C (mA) Min	C _{ob} (pF) Max	f _T (MHz) Min	t _{off} (ns) Max	NF (dB) Max	Test Conditions	Process No.		
2N3109	TO-39	80	40	7	10*	60	35	0.1	0.25	1.1	150	25	70	50	1000	7	5/6	
2N3110	TO-39	80	40	7	10*	60	40	0.1	1.0	2.0	1A	20	60	50	600	7	5/6 (See page 1-27)	12

NPN Transistors

Process 12 NPN Medium Power

Process 12



DESCRIPTION

Process 12 is a non-overlay, double-diffused, silicon epitaxial device. Complement to Process 67.

APPLICATION

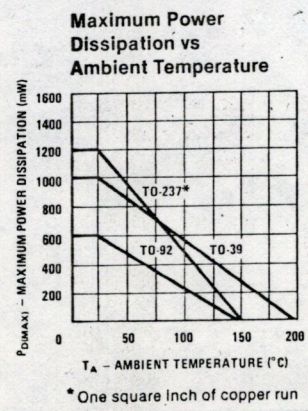
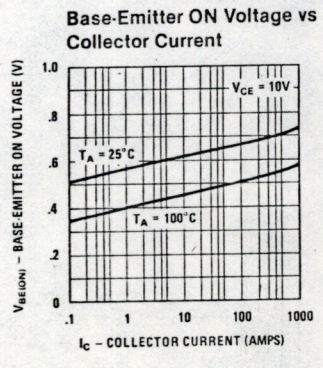
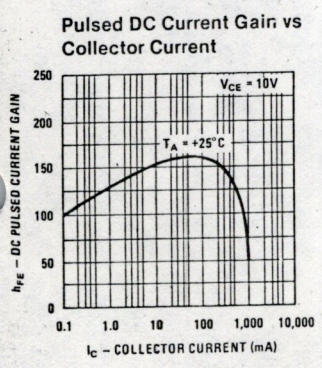
This device was designed for general purpose medium power amplifiers and switches requiring collector currents up to 1A and collector voltages up to 80V.

PRINCIPAL DEVICE TYPES

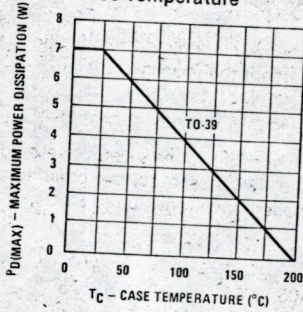
- TO-92, EBC: MPSA05
- TO-39: 2N3019
- TO-202: NSD106
- TO-237: TN3019, TN3020

Parameter	Conditions	Min	Typ	Max	Units	Notes
t_{ON}	$I_C = 150 \text{ mA}, I_{B1} = 15 \text{ mA}$		50		ns	Figure 1
t_{OFF}	$I_C = 150 \text{ mA}, I_{B2} = 15 \text{ mA}$		400		ns	Figure 1
h_{fe}	$I_C = 50 \text{ mA}, V_{CE} = 10V, f = 20 \text{ MHz}$	4.0	6.5			
C_{ob}	$V_{CB} = 10V, f = 1 \text{ MHz}$		6.5	10	pF	
C_{eb}	$V_{EB} = 0.5V, f = 1 \text{ MHz}$			60	pF	
h_{FE}	$I_C = 1 \text{ mA}, V_{CE} = 10V$	30				
h_{FE}	$I_C = 10 \text{ mA}, V_{CE} = 10V$	35				
h_{FE}	$I_C = 150 \text{ mA}, V_{CE} = 10V$	40	160	320		
h_{FE}	$I_C = 500 \text{ mA}, V_{CE} = 10V$	30				
$V_{CE(SAT)}$	$I_C = 100 \text{ mA}, I_B = 10 \text{ mA}$			0.2	V	
$V_{CE(SAT)}$	$I_C = 500 \text{ mA}, I_B = 50 \text{ mA}$			0.5	V	
$V_{BE(SAT)}$	$I_C = 100 \text{ mA}, I_B = 10 \text{ mA}$			0.90	V	
$V_{BE(SAT)}$	$I_C = 500 \text{ mA}, I_B = 50 \text{ mA}$			1.20	V	
BV_{CEO}	$I_C = 10 \text{ mA}$	65			V	
BV_{CBO}	$I_C = 100 \mu A$	100			V	
BV_{EBO}	$I_C = 10 \mu A$	7			V	
I_{CBO}	$V_{CB} = 80V$			100	nA	
I_{EBO}	$V_{EB} = 6V$			100	nA	

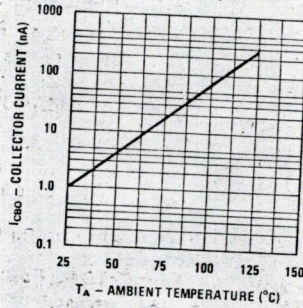
8



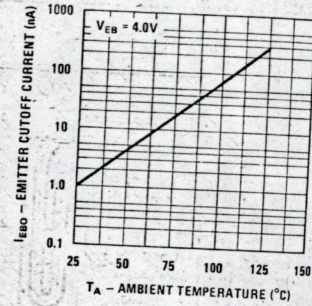
Maximum Power Dissipation vs Case Temperature



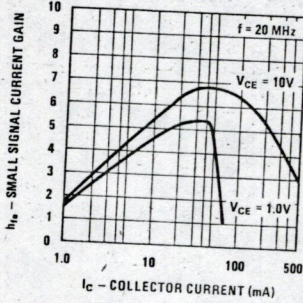
Collector Reverse Current vs Ambient Temperature



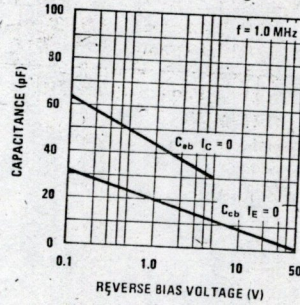
Emitter Cutoff Current vs Ambient Temperature



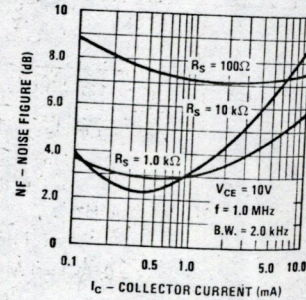
Small Signal Current Gain at 20 MHz



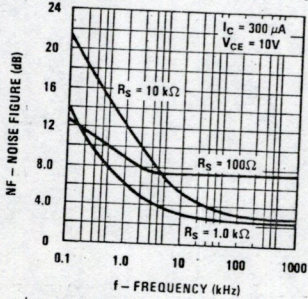
Collector-Base and Emitter-Base Capacitance vs Reverse Bias Voltage



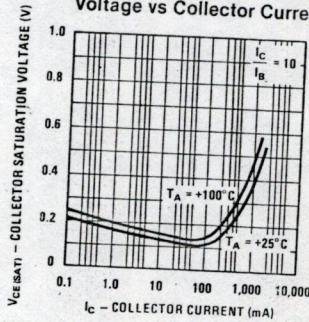
Noise Figure vs Collector Current



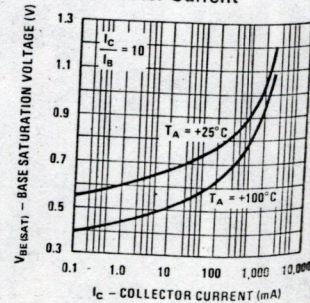
Noise Figure vs Frequency



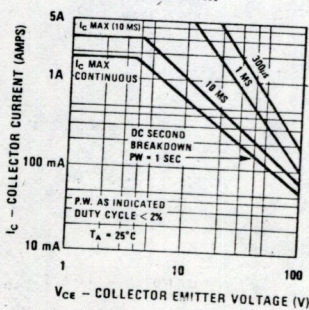
Collector Saturation Voltage vs Collector Current



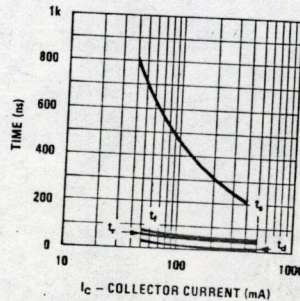
Base Saturation Voltage vs Collector Current



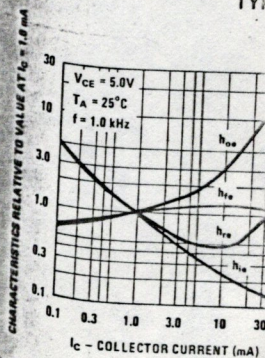
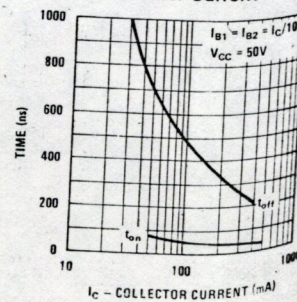
Safe Operating Area TO-39 with "Wake Field" Type 296-4 Heat Sink



Switching Times vs Collector Current



Turn On and Turn Off Times vs Collector Current

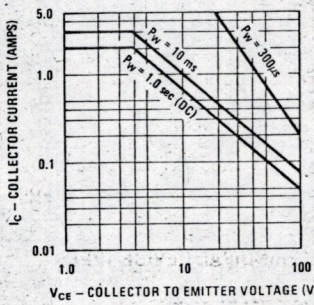


IC	150 mA	300 mA	500 mA
Symbol	h _{ie}	h _{oe}	h _{re}
Characteristics	Input Resistance	Output Resistance	Voltage Feedback Ratio

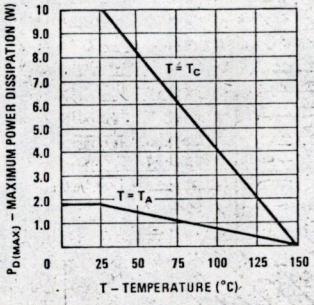
Process 12

Process 12

Safe Operating Area TO-202



Maximum Power Dissipation TO-202 vs Case and Ambient Temperature



I_C	R_b	R_L
150 mA	314 Ω	330 Ω
300 mA	157 Ω	167 Ω
500 mA	94 Ω	100 Ω

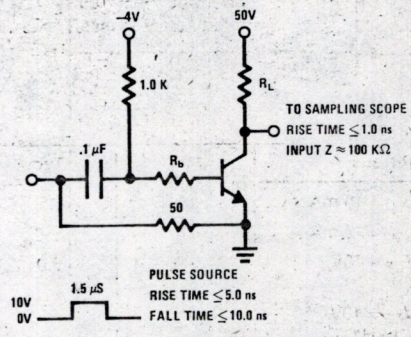
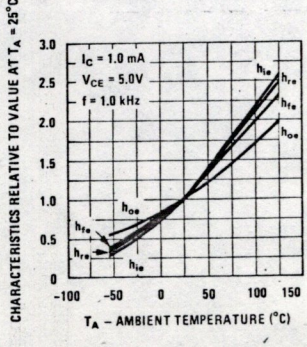
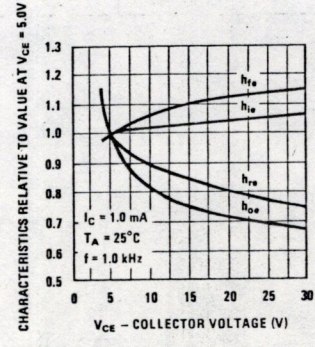
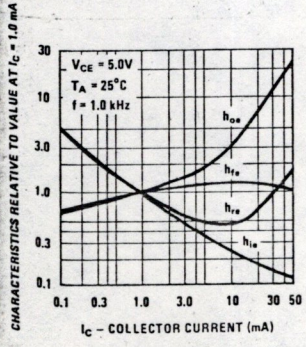


FIGURE 1. t_{ON} , t_{OFF} Test Circuit

SMALL SIGNAL CHARACTERISTICS (f = 1.0 kHz)

Symbol	Characteristic	Typ	Units	Conditions
h_{ie}	Input Resistance	3000	Ω	$I_C = 1.0 \text{ mA}$, $V_{CE} = 5.0 \text{ V}$
h_{oe}	Output Conductance	8.0	μmhos	$I_C = 1.0 \text{ mA}$, $V_{CE} = 5.0 \text{ V}$
h_{re}	Voltage Feedback Ratio	2.1	$\times 10^{-4}$	$I_C = 1.0 \text{ mA}$, $V_{CE} = 5.0 \text{ V}$
h_{fe}	Small Signal Current Gain	100		$I_C = 1.0 \text{ mA}$, $V_{CE} = 5.0 \text{ V}$

TYPICAL COMMON EMITTER CHARACTERISTICS (f = 1.0 kHz)



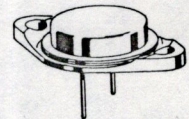
HIGH POWER NPN SILICON POWER TRANSISTOR

... EPIBASE transistors for ultimate circuit performance based on the designers requirements.

EPIBASE — designed for power amplifier and switching regulator applications. The best choice where high frequency response, low switching losses and good safe operating area are required.

- Current-Gain — Bandwidth Product — $f_T = 2.5 \text{ MHz (Min) @ } I_C = 1.0 \text{ Adc}$
- Safe Operating Area — Full Power Rating to 40 V

**15 AMPERE
POWER TRANSISTOR
NPN SILICON
60 VOLTS
115 WATTS**



*MAXIMUM RATINGS

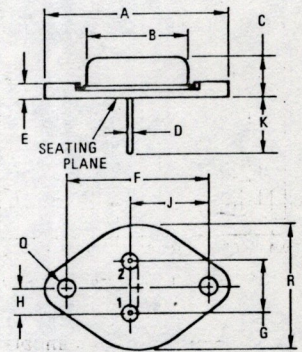
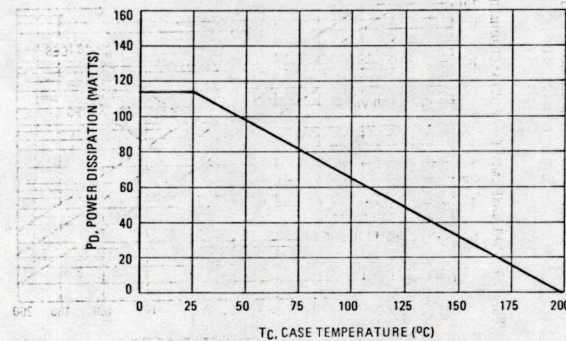
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Emitter Voltage Uni-Base	V_{CEX}^\dagger	90	Vdc
Collector-Emitter Voltage ($R_{BE} = 100 \Omega$)	V_{CER}	70	Vdc
Collector-Base Voltage	V_{CB}	100	Vdc
Emitter-Base Voltage	V_{EB}	7.0	Vdc
Collector Current — Continuous	I_C	15	Adc
Base Current	I_B	7.0	Adc
Total Device Dissipation $T_C = 25^\circ\text{C}$ Derate above 25°C	P_D	115 0.657	Watts W/ $^\circ\text{C}$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	$^\circ\text{C}$

*Devices selected from either process meet or exceed JEDEC Registration.
†Not a Registered Rating.

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.52	$^\circ\text{C/W}$

FIGURE 1 — POWER DERATING



STYLE 1:
PIN 1. BASE
2. EMITTER
CASE: COLLECTOR
NOTE: 1. DIM "Q" IS DIA.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	—	39.37	—	1.550
B	—	21.08	—	0.830
C	6.35	7.62	0.250	0.300
D	0.99	1.09	0.039	0.043
E	—	3.43	—	0.135
F	29.90	30.40	1.177	1.197
G	10.67	11.18	0.420	0.440
H	5.33	5.59	0.210	0.220
J	16.64	17.15	0.655	0.675
K	11.18	12.19	0.440	0.480
Q	3.84	4.09	0.151	0.161
R	—	26.67	—	1.050

CASE 11

ELECTRICAL CHARACTERISTICS ($T_C = 25^{\circ}\text{C}$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
* Collector-Emitter Sustaining Voltage ($I_C = 0.2 \text{ A dc}, I_B = 0$)	$V_{CE(sus)}$	60	—	Vdc
* Collector-Emitter Sustaining Voltage ($I_C = 0.2 \text{ A dc}, R_{BE} = 100 \Omega$)	$V_{CER(sus)}$	70	—	Vdc
* Collector Cutoff Current ($V_{CE} = 30 \text{ V dc}, I_B = 0$)	I_{CEO}	—	0.7	mAdc
Collector Cutoff Current ($V_{CE} = 100 \text{ V dc}, V_{EB(off)} = 1.5 \text{ V dc}$)	I_{CEX}	—	1.0	mAdc
($V_{CE} = 100 \text{ V dc}, V_{EB(off)} = 1.5 \text{ V dc}, T_C = 150^{\circ}\text{C}$)		—	5.0	
* Emitter Cutoff Current ($V_{BE} = 7.0 \text{ V dc}, I_C = 0$)	I_{EBO}	—	5.0	mAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 4.0 \text{ A dc}, V_{CE} = 4.0 \text{ V dc}$) ($I_C = 10 \text{ A dc}, V_{CE} = 4.0 \text{ V dc}$)	h_{FE}	20 5.0	70 —	—
Collector-Emitter Saturation Voltage * ($I_C = 4.0 \text{ A dc}, I_B = 0.4 \text{ A dc}$) ($I_C = 10 \text{ A dc}, I_B = 3.3 \text{ A dc}$)	$V_{CE(sat)}$	—	1.1 3.0	Vdc
Base-Emitter On Voltage ($I_C = 4.0 \text{ A dc}, V_{CE} = 4.0 \text{ V dc}$)	$V_{BE(on)}$	—	1.5	Vdc
Second Breakdown Collector Current With Base Forward-Biased ($t = 1.0 \text{ s}$) ($V_{CE} = 40 \text{ V dc}$)	$I_{S/b}$	2.87	—	A dc
DYNAMIC CHARACTERISTICS				
Current-Gain – Bandwidth Product ($I_C = 1.0 \text{ A dc}, V_{CE} = 4.0 \text{ V dc}, f_{test} = 1.0 \text{ MHz}$)	f_T	2.5	—	MHz
* Small-Signal Current Gain ($I_C = 1.0 \text{ A dc}, V_{CE} = 4.0 \text{ V dc}, f = 1.0 \text{ kHz}$)	h_{fe}	15	120	—

*Indicates JEDEC Registered Data.

FIGURE 2 – SWITCHING TIMES TEST CIRCUIT

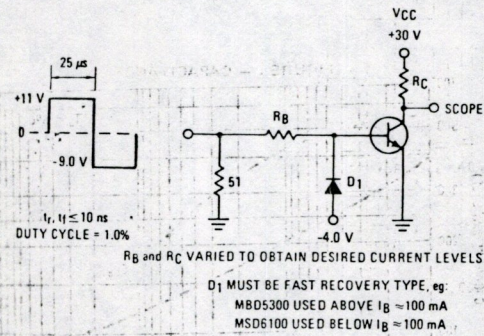


FIGURE 3 – TURN-ON TIME

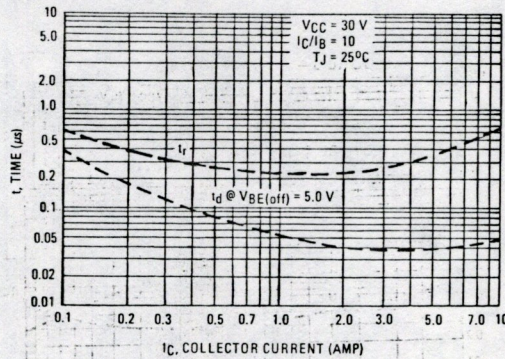
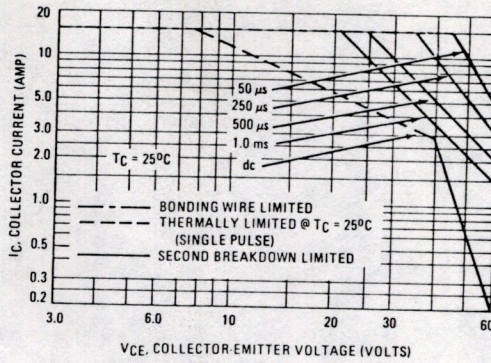


FIGURE 4 - ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation, i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

Second breakdown pulse limits are valid for duty cycles to 10%. At high case temperatures, thermal limitations may reduce the power that can be handled to values less than the limitations imposed by second breakdown. (See AN-415).

FIGURE 5 - COLLECTOR CUT-OFF REGION

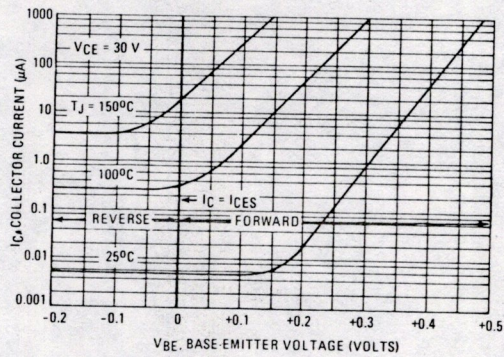


FIGURE 6 - TURN-OFF TIME

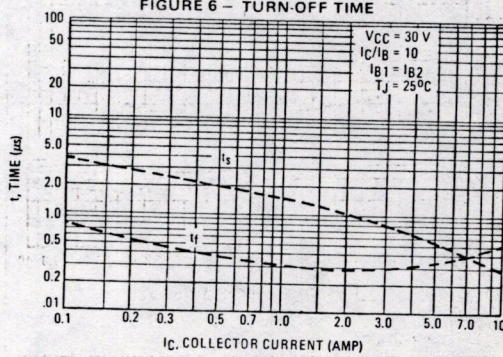


FIGURE 7 - CAPACITANCE

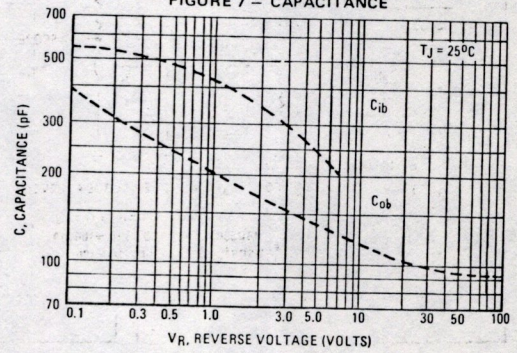


FIGURE 8 - DC CURRENT GAIN

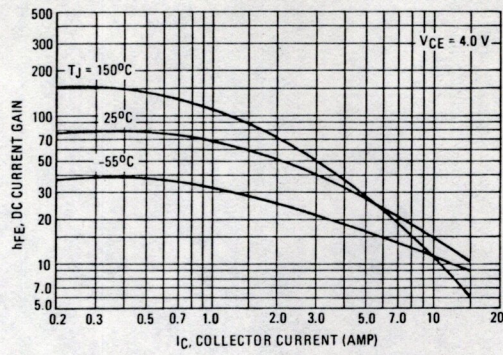


FIGURE 9 - COLLECTOR SATURATION REGION

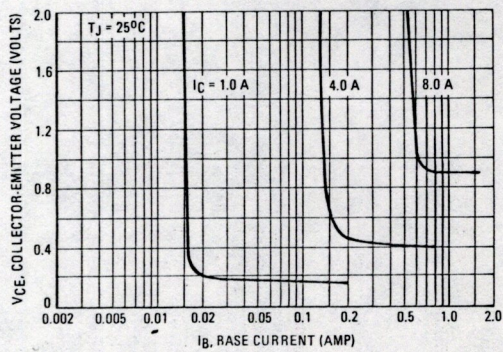
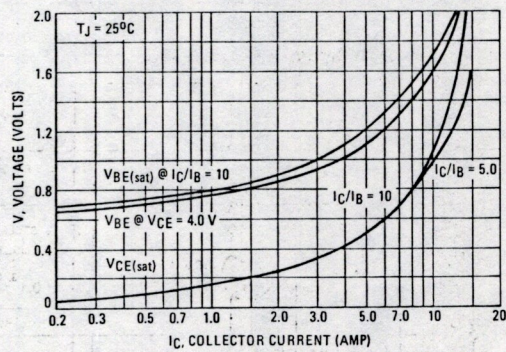


FIGURE 10 - "ON" VOLTAGES



SWAC Jacks - From the REAR

Blue
④

White
③

Red
②

Yellow
①
Black

42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE
MADE IN U.S.A.

