POWER MODULE - DUAL STAGE DRAWER

TYPES 35 AND 70

Schematic Diagram 874D785
Wiring Diagram 880D181

FUNCTION

The power module is a drawer containing two complete inverter stages. (Refer to photograph.) The Types 35 and 70 differ only in rating, having identical schematic and mechanical arrangements. These power modules are used to make up complete inverters of the desired power level and number of stages required for a particular application. The following description will apply to only one complete inverter stage.

The function of the inverter stage is to produce single-phase, square-wave AC output power when operated from a fixed DC bus volt. (Refer to "Basic Theory".) This is achieved by a single-phase bridge arrangement of four switching thyristors, which are caused to switch in sequence and timing determined by logic signals from the counter/driver board. The output of the single-phase inverter stage is applied to a single-phase transformer which is then connected to the load.

The AC single-phase power frequency thus produced will be in synchronism with the master oscillator. The average voltage output of the stage is controlled by the duration of the ON time of positive and negative half cycles, as determined by the logic signals.

OPERATION

Operation of the inverter stage is most easily seen by referring to the schematic and examining the following separate sections:

1. The power switching thyristors, SCR11-SCR12-SCR21-SCR22;
2. The turn-off or commutating circuitry, consisting of reactors 11L and 21L, capacitors 11C-12C and 21C-22C;
3. Free-wheeling circuitry to handle the flow of reactive load current, consisting of diodes 13D-14D-23D-24D and damping resistance connected externally by RRP and RRN;

4. Special circuitry for recovery of excess commutation energy, which comprises reactors 13L-15L-23L-25L and diodes 11D-12D-21D-22D; and
5. Protective circuitry which includes current-limiting fuses, surge suppressors, and thyristor delay reactors 12L-22L-24L.

Each of these sections will be described separately for clarity.

A. Power Switching Operation

Referring to schematic diagram 874D785, it is seen that the switching thyristors are arranged in a single-phase bridge circuit, with the DC power bus connected at one pair of terminals (marked + 300 DC and 0 V DC), and the load connected at the other pair of terminals (marked AC1 and AC2) of the bridge. It will be noted that each half of the bridge is symmetrical (left and right). Furthermore, the upper and lower thyristors are always switched at the same time in a complementary manner: that is, when SCR11 is ON then SCR12 is OFF, and when SCR12 is ON then SCR11 is OFF. This must always be the case since simultaneous ON conditions for both SCR11-SCR12 would result in a short-circuit directly across the DC bus, blowing the protective fuse 1FU. With these points kept in mind, the operation of a complete cycle of power flow will be discussed.

Figure 1 shows typical single-phase voltage waveforms seen at the output of any one power stage. The waveshape at maximum frequency or rated frequency will show almost complete conduction during positive and negative half cycles. The waveshape at minimum frequency in adjustable frequency inverter will show a conduction of perhaps only 30 degrees out of the possible 180 degrees. Full 180-degree conduction will only occur at maximum design frequency under conditions of low input line voltage. This is, in effect, a safety margin which permits maximum output even with low DC bus voltage input. Of course, if the voltage falls below the designed limits as specified, then malfunction may be expected to occur, depending on factors of loading, frequency, etc.

Figure 2 shows a typical mid-frequency range, nominal DC voltage, voltage waveshape, with load current superimposed. (Because of the output transformer interconnections, this current is very nearly sinusoidal.) This particular case shows unity power factor loading (resistive load), since current is shown in phase with the voltage. The current flow may be divided into six parts, shown shaded, and the path of current flow examined for each part of the cycle.

1. During interval A (SCR11-22 ON), current and voltage are both positive, producing positive power output to the load. Current flow is: from +300 DC, through SCR11 to the load AC1-AC2, then through SCR22 to the negative bus OVDC.

2. During interval B (SCR11-21 ON), voltage is zero while the current is still positive. This represents no power output to the load from this stage, but merely a free-wheeling of current. Current flow is: from the load at AC2, through diode 23D to RRP, through an external damping resistor at plugs 6-7 to +300 DC, through SCR11 and back to the load at AC1.

3. During interval C (SCR11-21 ON), the voltage is still zero but the current has reversed direction. The new free-wheeling path for current flow is: from the load at AC1, through diode 13D to RRP, through the external damping resistor at plugs 6-7 to +300 DC, through SCR21 and back to the load at AC2.

4. During interval D (SCR12-21 ON), the voltage and current are both negative, again producing <u>positive</u> power output to the load. Current flow is: from +300 DC, through SCR21 to the load AC2-AC1, then through SCR12 to the negative bus OVDC.

5. During interval E (SCR11-21 ON), free-wheeling again takes place. The current flow is identical to interval C.

6. During interval F (SCR11-21 ON), free-wheeling continues but with current flow reversed. The current flow is identical to interval B.

NOTE: Observe from the above, that during every interval either SCR11 or SCR21 is switched ON. It is for this reason that these thyristors are referred to as "ON-dominant". Conversely, thyristors SCR12 and SCR22 are termed "OFF-dominant". This is convenient to remember when considering waveforms.

The preceding case described a resistive or unity power-factor load. This is not typical, however, of most loads which are normally inductive in nature. For <u>this</u> case, refer to Figure 3 which shows lagging the voltage by a <u>full</u> 90 degrees. Again, the cycle is divided into six intervals.

1. During interval A (SCR11-22 ON), current and voltage are both positive, producing positive power output to the load. Current flow is: from +300 DC, through SCR11 to the load AC1-AC2, then through SCR22 to the negative bus OVDC.

2. During interval B (SCR11-21 ON), voltage is zero while the current is still positive. This is a free-wheeling condition, with current flow as follows: from the load at AC2, through diode 23D to RRP, through an external damping resistor at plugs 6-7 to +300 DC, through SCR11 and back to the load at AC1.

3. During interval C (SCR12-21 ON), the voltage has reversed while the current continues in the positive direction. This represents negative, or regenerative power from the load, which must be pumped back to the DC power supply. This power obviously does not go backward through the rectifier supply, but does help supply power to the other stages of the inverter. In addition, a large input capacitor stores excess energy during part of the cycle. Current flow is: from the load at AC2, through diode 23D to RRP, then through the external damping resistor at plugs 6-7 to +300 DC, next through the DC supply bus to OVDC (regeneration), then through the external damping resistor at plugs 2-3 to RRN, through diode 14D and back to the load at AC1.

4. During interval D (SCR12-21 ON), the current finally reverses and flows in the same direction as the negative voltage. This is now positive power flow again to the load. The current path is: from +300 DC, through SCR21 to the load at AC2-AC1, then through SCR12 to the negative bus OVDC.

5. During interval E (SCR11-21 ON), free-wheeling takes place. Current flow is: from the load at AC1, through diode 13D to RRP, through the external damping resistor at plugs 6-7 to +300 DC, through SCR21 and back to the load at AC2.

6. During interval F (SCR11-22 ON), regeneration again takes place because the load current opposes the stage applied voltage. Negative power is taken from the load and pumped back to the DC supply. Current flow is: from the load at AC1, through diode 13D to RRP, then through the external damping resistor at plugs 6-7 to +300 DC, next through the external damping resistor at plugs 2-3 to RRN, through diode 24D and back to the load at AC2.

NOTE: Observe again that during every interval, either SCR11 or SCR12 is switched ON, showing the ON-dominant nature of these thyristors. Conversely, SCR12 and SCR22 are OFF-dominant.

B. Turn-off, or Commutating Operation

The turn-off mechanism for thyristor switches has been discussed in the section on "Basic Theory". On schematic diagram 874D785, the commutating capacitors which store the switching energy are 11C-12C and 21C-22C. The commutating reactors are 11L and 21L, center tapped.

C. Free-wheeling Operation

Free-wheeling operation has been discussed under Section A, "Power Switching Operation". The elements utilized for the free-wheeling circuit include diodes 13D-23D, and the external damping resistor across plugs 6-7. During regeneration, the free-wheeling takes place with diodes 14D-24D, and the external resistor across plugs 2-3.

D. Recovery Circuit Operation

Since fixed values of commutating capacitors are used, each switching discharges the same amount of energy regardless of varying load requirements. These capacitors are designed to produce reliable turn-off when peak load is being switched, when minimum line voltage is being switched, when minimum line voltage is present, and when the load power factor is worst. Under normal conditions, the amount of switching energy required to turn off the thyristors is much less than the design amount. Unless some form of recovery circuit is used, this energy must be dissipated, and usually it would be through the thyristors. For these reasons, special circuitry has been added to the AccurCon Inverter stages to recover the bulk of this energy, resulting in much greater efficiency, and placing less strain on the semiconductor elements.

Each thyristor is shunted with a combination of reactance and a diode. These are 11D-13L, 12D-15L, 21D-23L, and 22D-25L. During actual commutation, the turn-off current switches through this circuit after the thyristor blocks. The current is then passed to the DC bus and recovered, instead of being dissipated in the devices. The greatest value of this circuitry is for light load operation, where the low requirements of turn-off would otherwise cause a great amount of energy to be wasted.

E. Protective Circuitry

Protection of the semiconductor elements falls into two main categories: overcurrent and surge suppression, both of which can cause failure in extremely short times. The thyristors across the DC bus form a path for short circuit if both should remain ON for even a few milliseconds. For this reason, fast-acting current-limiting fuses are provided to protect against thyristor damage during a mis-fire. These fuses have been very carefully selected and coordination with the specific thyristors used, and they must never be replaced with any other type of fuse without specific approval of the inverter manufacturer. Each fuse is arranged with a trigger fuse in parallel, which actuates a plunger upon blowing. The plunger then actuates the stage indicating light, and any alarm relay circuitry which may be used.

Surge suppression is provided by an RC suppressor around each semiconductor which is exposed to transients. This prevents rapidly changing voltages from imposing stress on the thyristor itself. The recovery diode 11D is likewise protected. The stage filter capacitors also afford protection from certain transient conditions.

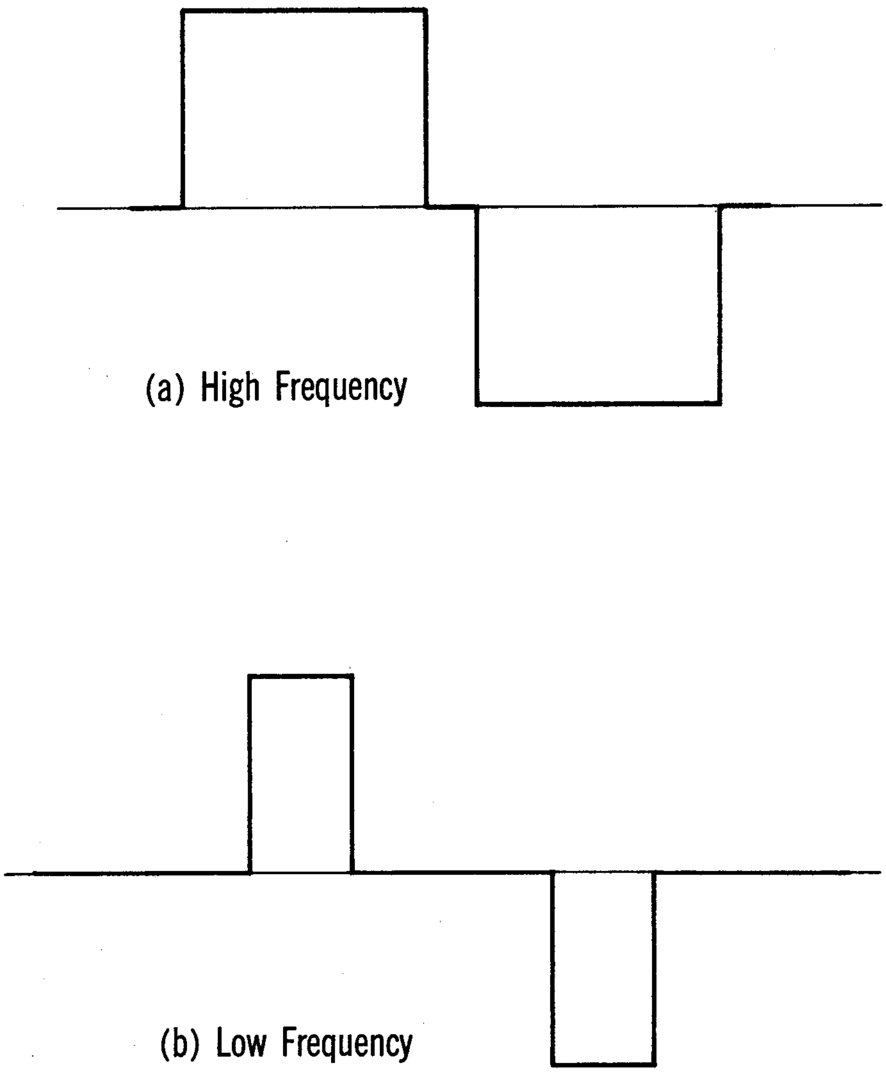
Another form of protection for the thyristors is the delay reactor in series with each thyristor. These are delay reators 12L-14L-22L-24L. Their purpose is to delay slightly the build-up of anode current after the instant of firing, in order to permit the thyristor crystal to become fully conducting before carrying full current. This is important in avoiding thyristor degradation which can be caused by excessive di/dt rates over a period of time.

TESTING

The output waveform of the stage is a good indication of the proper operation of that stage. When the output wave is clean and square, the stage is operating correctly. Loss of a fuse will usually produce a half wave only, or at best, a rounded full wave. In such cases, individual elements should be checked. An oscilloscope across the diodes or thyristors will indicate whether these are operating properly.

Occasionally, a thyristor can be marginal in operation, giving rise to erratic fuse blowing. This condition can best be determined by measuring the forward gate voltage drop. Most units will show a gate drop of 5 volts or less. Thyristors with greater gate drop should be replaced, or tested very thoroughly outside the stage circuitry. A more positive indication of thyristor deterioration is given by any appreciable change in gate voltage drop. It is good practice to measure the gate drop of each thyristor with an oscilloscope, and to note this value in writing for record purposes. A simple sticker may be affixed to the stage drawer. Good maintenance procedure would be to measure this value every six months, or whenever the unit is shut down for other reasons. If the gate voltage drop has changed appreciably, then the thyristor should be replaced.

For convenience in testing, the schematic diagram is marked with lettered points, which are molded into the half stage. In addition, the drawer wiring diagram indicates clearly the location of all parts of the drawer.



(a) High Frequency

(b) Low Frequency

FIGURE 1 - TYPICAL STAGE OUTPUT WAVEFORMS

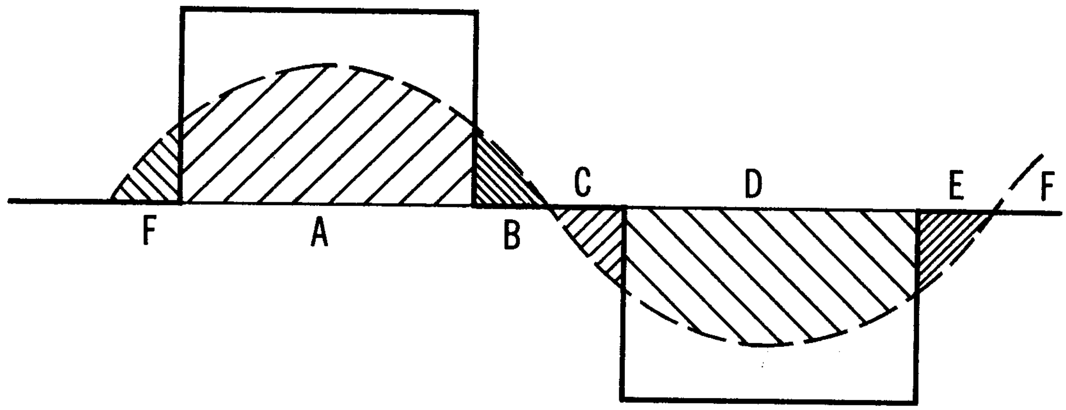


FIGURE 2 - STAGE OUTPUT, RESISTIVE LOAD

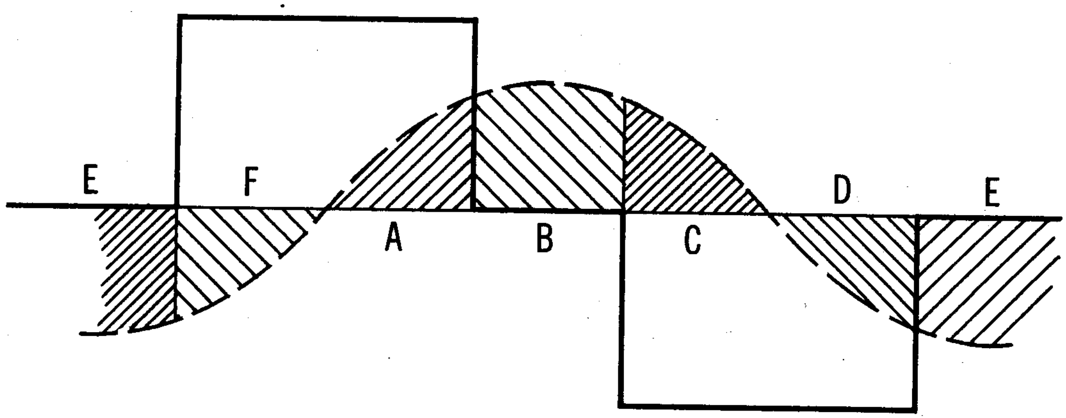
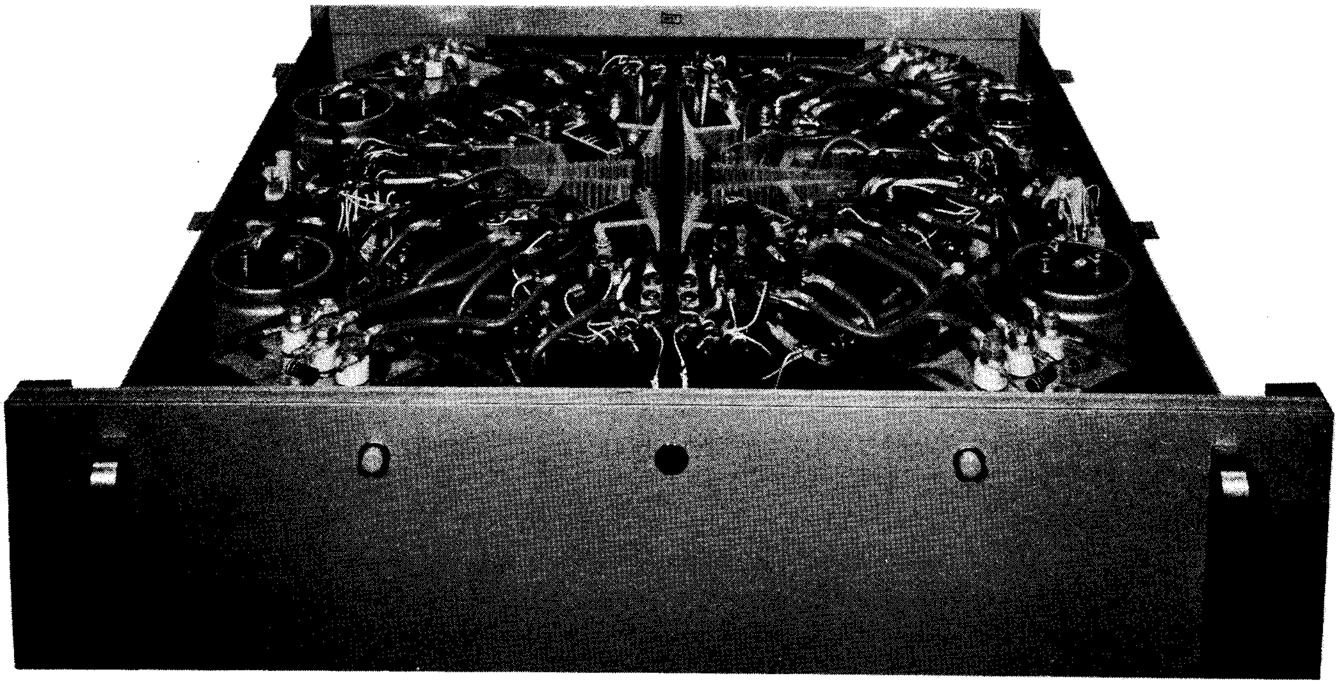
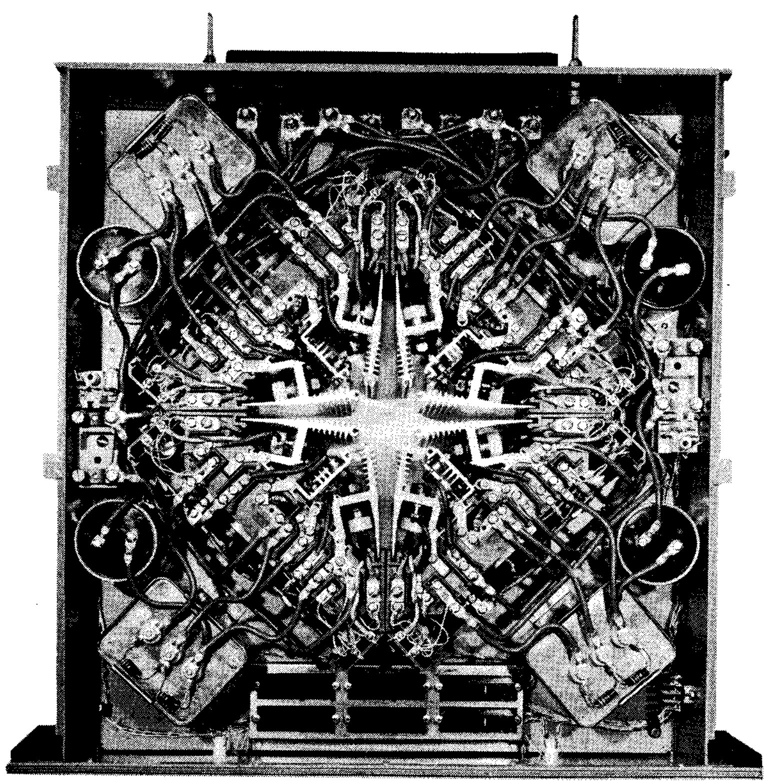


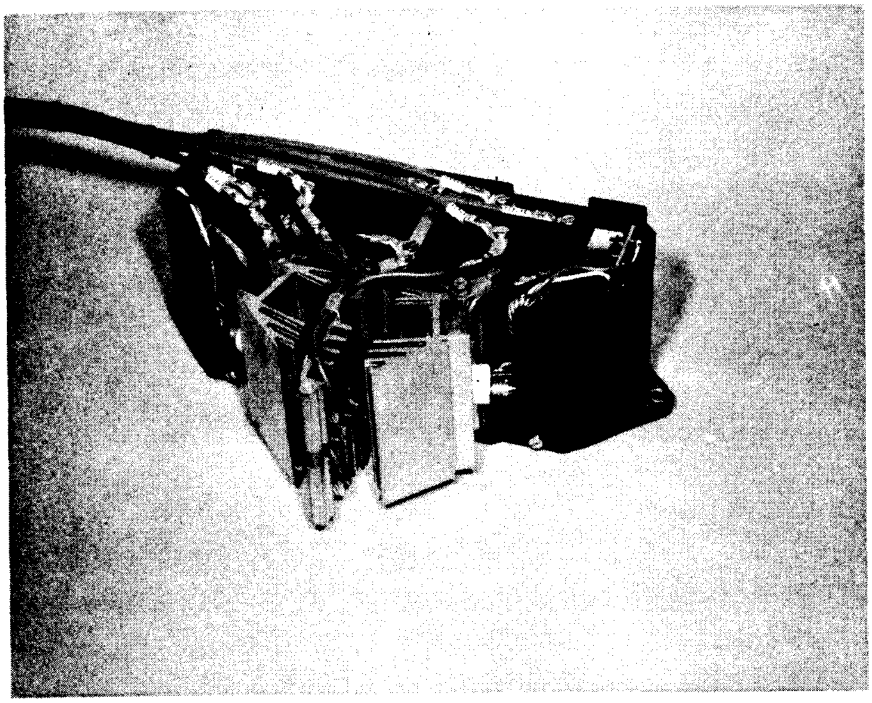
FIGURE 3 - STAGE OUTPUT, INDUCTIVE LOAD



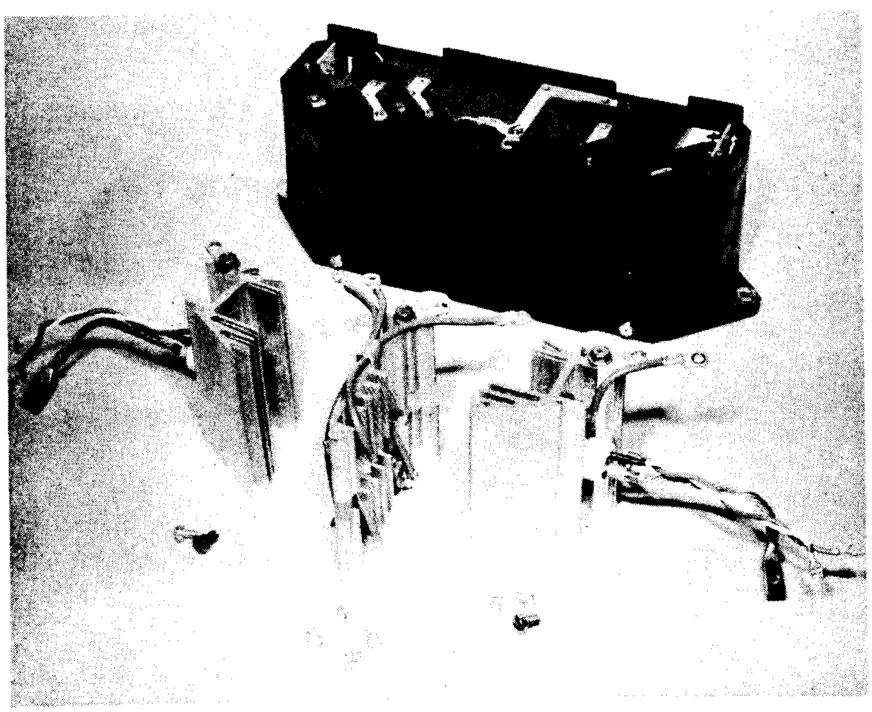
TYPE 35 DUAL-STAGE DRAWER



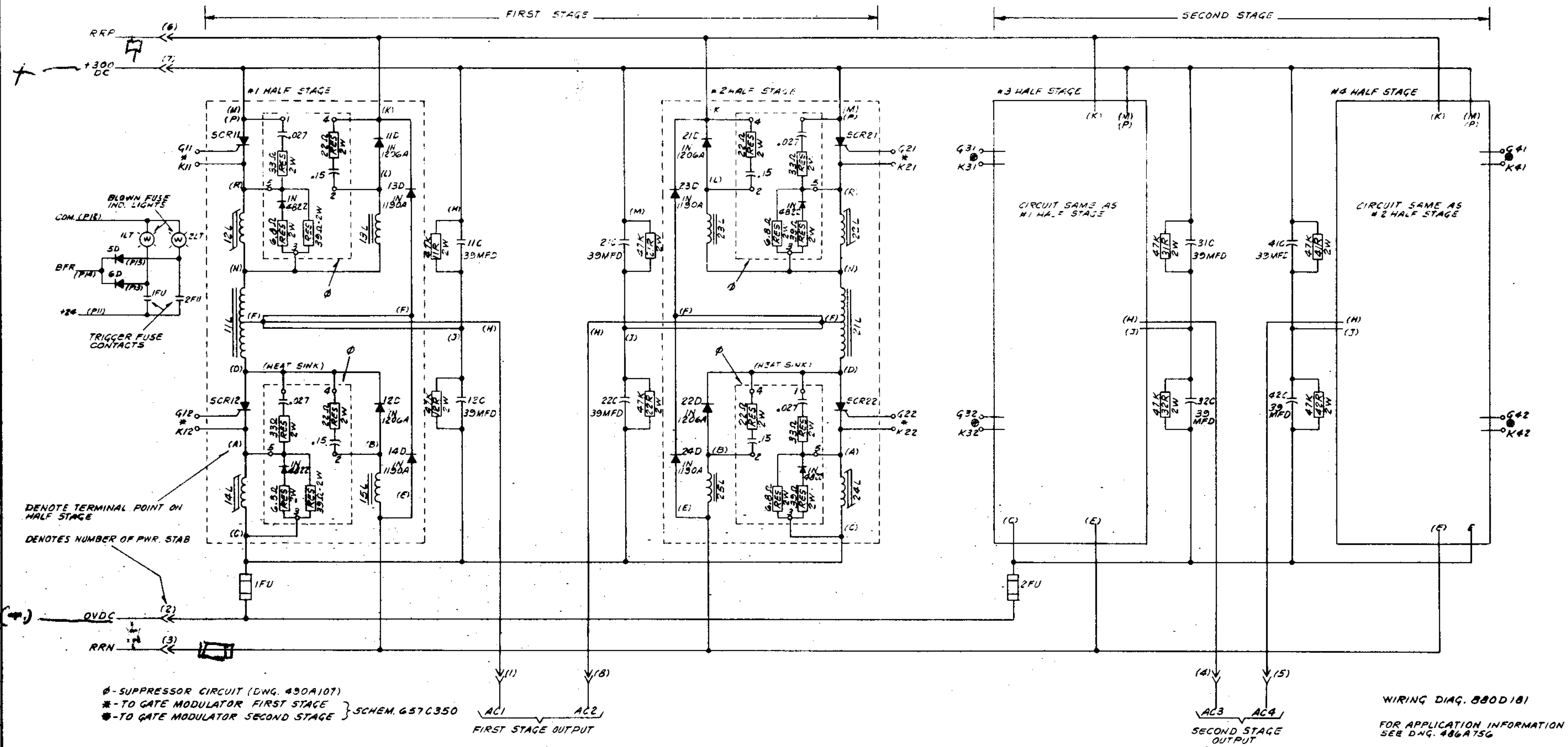
TYPE 35 DUAL-STAGE DRAWER



TYPE 70 HALF-STAGE ASSEMBLY



TYPE 70 HALF-STAGE ASSEMBLY



ø - SUPPRESSOR CIRCUIT (DWG. 430A107)
* - TO GATE MODULATOR FIRST STAGE
⊕ - TO GATE MODULATOR SECOND STAGE
} SCHEM. 657C350

WIRING DIAG. 880D181

FOR APPLICATION INFORMATION SEE DWG. 486A756

DWG. 874D785 SUB. 134

WESTINGHOUSE ELECTRIC CORPORATION

TITLE: INVERTER TYPE 78 DOUBLE STAGE POWER MODULE SCHEMATIC

S. LASKOWSKI

GEN. CONTROL

874D785

CIR. WAS MOD. TRACGER WITH NEW PWR. MODULE — 7-21-66

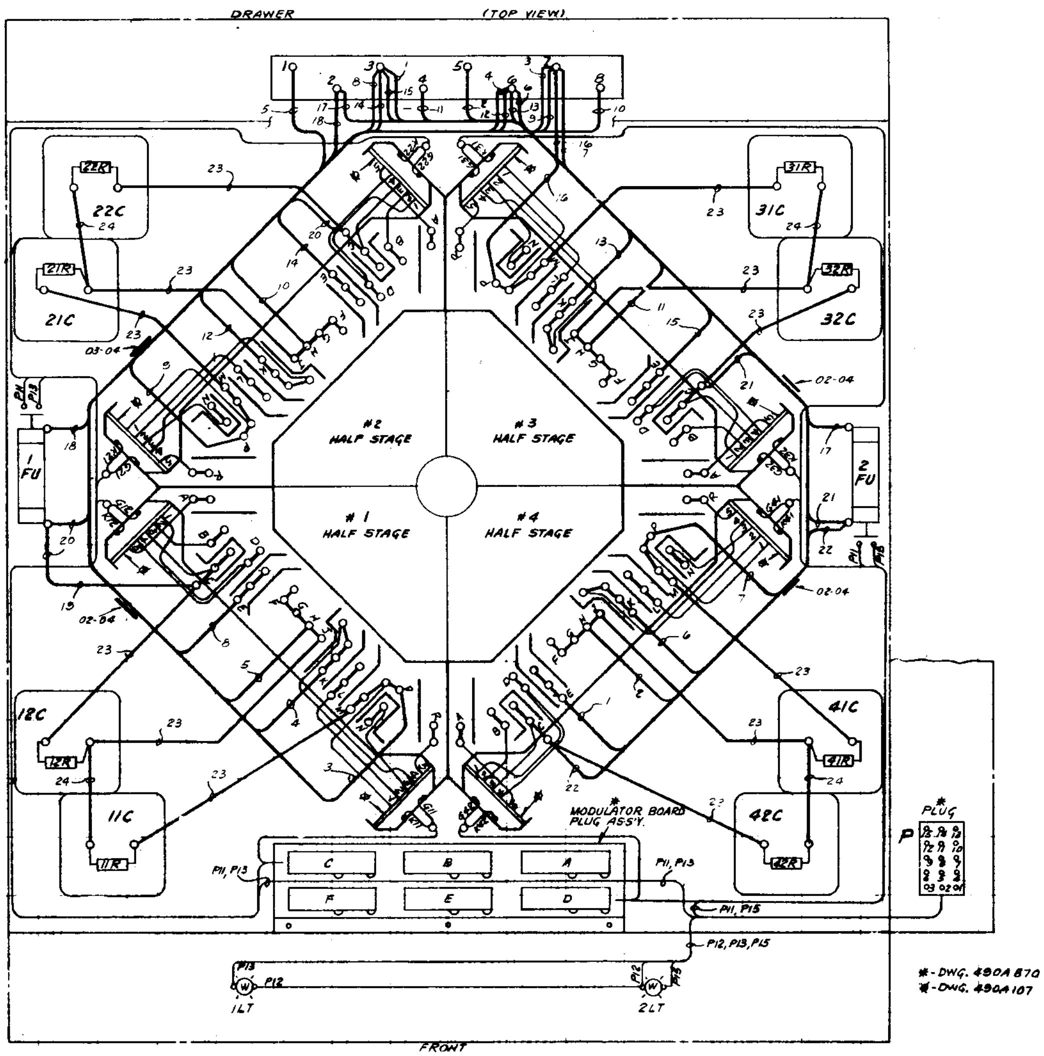
FUTURE SUPPRESSOR INTERCHANGED — S.L. 11-21-66

TITLE INVERTER POWER MODULE TYPE 70

DWG. 880D181 SUB. [illegible] PUNCH CHART

SYM.	ITEM	DESCRIPTION - MATERIAL			STYLE NO.	REQ.	TOOL NUMBER
	01	CONN. PER TABLE BELOW				GRP	
	02	WIRE SPACER			200B462H[illegible]	3	
	03	WIRE SPACER			200[illegible]H[illegible]	1	
	04	WIRE WRAP			[illegible]	4	

GRP	DESCRIPTION	ITEMS ON THIS DWG	REQ
30	CONN. COMP.	01 TO 04 GRP 1 TO 24	1



CONN TABLE

CONNECTION			WIRE SIZE		WIRE	TERMINAL SH					REQ	REMARKS
GROUP NUMBER	FROM	TO	[illegible]	[illegible]	LENGTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
1	4-E	STB-3	X		32.25				X	X	1	
2	4-H	STB-5	X		27.25				X	X	1	
3	1-P	STB-7	X		37.75				X	X	1	
4	1-K	STB-6	X		[illegible]				X	X	1	
5	1-H	STB-1	X		25.25				X	X	1	
6	4-K	STB-6	X		24.25				X	X	1	
7	4-P	STB-7	X		[illegible]				X	X	1	
8	1-E	STB-3	X		22.5				X	X	1	
9	2-P	STB-7	X		[illegible]				X	X	1	
10	2-H	STB-8	X		18				X	X	1	
11	3-H	STB-4	X		[illegible]				X	X	1	
12	2-K	STB-6	X		13.75				X	X	1	
13	3-K	STB-6	X		[illegible]				X	X	1	
14	2-E	STB-8	X		5.875				X	X	1	
15	3-E	STB-8	X		12.75				X	X	1	
16	3-P	STB-7	X		5.5				X	X	1	
17	2FU	STB-2		X	16.75		X	X			1	
18	1FU	STB-2		X	[illegible]		X	X			1	
19	1-C	1FU	X		2.5	X			X		1	
20	2-C	1FU	X		19.5	X			X		1	
21	3-C	2FU	X		.5	X			X		1	
22	4-C	2FU	X		10.75	X			X		1	
23	#	#	X		3.75				XX		16	
24	Δ	Δ	X		[illegible]				XX		8	

- THESE WIRES CONNECT POINTS G.J. AND [illegible] ALL FOUR STAGES TO THEIR [illegible]

Δ - THESE WIRES ARE JUMPERS [illegible]

*- DWG. 490A870

\#- DWG. 490A107

SCHEMATIC 830D782

880D181