

INSTALLATION • OPERATION • MAINTENANCE I N S T R U C T I O N S

TYPE SDF-1 SOLID STATE UNDERFREQUENCY RELAY

CAUTION: It is recommended that the user of this equipment become acquainted with the information in this instruction leaflet before energizing the equipment. Failure to observe this precaution may result in damage to the equipment.

Printed circuit modules should not be removed or inserted while the relay is energized unless specific instructions elsewhere in this instruction leaflet state that such action is permissible. Failure to observe this precaution can result in an undesired tripping output, and cause component damage.

APPLICATION

The SDF-1 Relay (Figures 1 & 2) is a solid state, single-frequency-setting, high-accuracy under-frequency relay for use in automatic load-saving schemes. (See setting section page 4 for further application data.)

CONSTRUCTION & OPERATION

The type SDF-1 Underfrequency Relay is composed of (1) an isolation transformer, (2) a zero crossing voltage detector, and synchronizer printed circuit module, (3) a main clock and four bit binary counter printed circuit module, (4) a twelve bit binary counter printed circuit module, (5) a trip control circuit and delay timer printed circuit module, (6) a power supply printed circuit module, (7) a front panel mounted digital underfrequency trip-point setting assembly, (8) a trip relay, and (9) an indicating contactor switchunit (ICS).

All components are identified on the internal schematic in Figure 3.

ISOLATING TRANSFORMER

The isolation transformer is a 1:1 transformer which provides dc isolation.

ZERO CROSSING, VOLTAGE DETECTOR, AND SYNCHRONIZER PRINTED CIRCUIT MODULE

The zero crossing, voltage detector, and synchronizer printed circuit module contains a two-cell symmetrical low pass filter to provide transient and high frequency noise suppression, a zero crossing detector that generates a low voltage square wave signal having the same frequency as the fundamental of the input signal, and a synchronizer for the synchronization of the output signals from the zero-crossing detector with the main clock signals. Also contained on this module are the two power supply voltage detectors to prevent spurious tripping at the time of power turn-on, and an undervoltage detector which provides an inhibiting signal to avoid incorrect operation of the relay if the input line voltage drops below the minimum prescribed value (25 to 40 volts.) Refer to Figure 5 for component location and board layout.

MAIN CLOCK AND FOUR BIT BINARY COUNTER PRINTED CIRCUIT MODULE

The main clock and four bit binary counter printed circuit module contains the main clock and the first four bits of the binary counter. The main clock, consisting of a crystal controlled oscillator to provide the reference frequency and a driving state, supplies clock pulses to the main counter and to the synchronizer. The first four bits of the 16-bit binary counter are also contained on this module. Refer to Figure 6 for component location and board layout.

SUPERSEDES I.L. 41-504A

*Denotes change from superseded issue.

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TWELVE BIT BINARY COUNTER PRINTED CIRCUIT MODULE

The twelve bit binary counter printed circuit module contains the last 12 bits of the 16 bit binary counter and the timing control circuit. The timing control circuit accomplishes the generation of the proper signals required by the trip control circuit to perform the specified trip enabling or inhibiting sequences * as well as generation of the reset signal for the binary counter. Refer to Figure 7 for component location and board layout.

TRIP CONTROL CIRCUIT AND DELAY TIMER PRINTED CIRCUIT MODULE

The trip control circuit and delay timer printed circuit module contains the coincidence output circuit, a trip control circuit, a trip timer, and a trip output circuit. The coincidence output circuit generates a signal that is stored by the trip control circuit when the period set on the underfrequency trippoint setting is exceeded. The trip control circuit stores the information whether or not a trip condition occurred during the actual cycle and before the reset signal initiates the next period timing. This circuit also steps up one of the required counting sequences of three consecutive trip cycles for tripping or two consecutive no-trip cycles required for reset. The trip timer starts after the first trip cycle is recognized. Before three consecutive trip cycles have occurred it is reset by the first no-trip cycle; after three consecutive trip cycles have occurred it is reset only if two consecutive no-trip cycles occur. The timer energizes the trip output circuit after the delay time is expired. The delay time, after the first trip cycle is recognized, can be set from 1 to 99 cycles (60 Hz base) with the front panel decade switches; the prescribed range however goes from a minimum of 2 cycles, since three consecutive trip cycles are required by the trip control circuit for a trip condition, to a maximum of 99 cycles. The trip output circuit provides the required signal characteristics in order to drive the trip relay. The trip output circuit is set in the trip condition by the completion of the trip delay time and is reset by either a low voltage inhibit signal or the trip control circuitry. Refer to Figure 8 for component location and board layout.

POWER SUPPLY PRINTED CIRCUIT MODULE

The power supply printed circuit module contains a

dual voltage regulated switching power supply with an 18 volt dc output for most relay functions and a 5 volt dc output for the integrated circuit functions. The main supply is of the switching regulator design giving high efficiency and relative insensitivity to input voltage. The initial turn on circuitry of the supply prevents false starts and provides non-destructive short circuit protection which, if the output is shorted, requires dc supply voltage to be removed and reapplied to restart the power supply. Refer to Figure 9 for component location and board layout.

DIGITAL UNDERFREQUENCY TRIP-POINT SETTING ASSEMBLY

The digital underfrequency trip-point setting assembly is where the frequency trip-point is set as maximum allowed period. The setting corresponds to the binary coded number of main clock pulses that can be counted during the maximum period duration. If the actual period exceeds the set value, the coincidence generates a signal to the trip control circuit.

The two trip delay timer decade setting switches are located on the underfrequency trip-point setting assembly and can be set in any combination yielding from 2 to 99 cycles of time delay (60 Hz base).

TRIP RELAY

The operation of the trip relay is controlled by the trip output circuit on the trip control circuit and delay timer printed circuit module. The trip relay, when energized, allows the indicating contactor switch unit to operate.

Indicating Contactor Switch Unit (ICS)

The indicating contactor switch is a small d-c operated clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch which allows the operation indicator target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

on the main clock and 4 bit binary counter printed circuit module by a stable crystal oscillator which uses the parallel resonance of the crystal CL-1 in the circuitry associated with field-effect transistor Q8 to produce a 1.966080 megahertz clock signal, CPO.

The 16 bit binary counter is located on the main clock and four bit binary counter printed circuit module (bits [0], [1], [2], and [3],) and the twelve bit binary counter printed circuit module (bits [4] through [15]). With a 1.966080 MHz clock frequency (CPO), bit [15] changes status every 16.6667 milliseconds. Since all the bits of the counter are reset to ZERO at the beginning of each period [15] goes to "1" only if the actual period is longer than the 60 Hz period. For frequencies ranging from 60 to 54 Hz the actual period ranges from 16.6667 to 18.5185 milliseconds. When [15] goes to "1" all bits from [0] to [14] go to ZERO. During the 1.8518 ms corresponding to the difference between 54 and 60 Hz periods there are 1821 CP1 clock pulses. (Bit [0] is used as a scaling stage to obtain a CP1 output at half the frequency of CPO). With the condition [15] = ONE, only the first 11 bits must be then decoded to detect if the input frequency falls below a preset value from 60.00 Hz to 54.00 Hz set on the digital underfrequency trip-point setting assembly per Table 1. This is accomplished by the coincidence circuit generating a signal to the trip control circuitry where it is stored and utilized in a manner previously described.

CHARACTERISTICS

FREQUENCY RANGE (HZ)

The SDF-1 relay can be set at values from 54.00 to 60.00 Hz in increments of 0.05 Hz, with an accuracy of ± 0.007 Hz from the set point. The repeatability is thus ± 0.007 Hz.

(See Table I)

Increments of less than 0.05 Hz can be obtained if needed for unusual applications.

D.C. CONTROL VOLTAGE

The SDF-1 relay is designed to operate on either 48 or 125 volts d.c. with no settings or adjustments required. The operating range is 42 to 140 volts dc.

ENERGY REQUIREMENTS

AC Burden	7.3 Volt-Amperes at 120VAC 60 Hz.
DC Burden	14 Watts at 48 VDC Control Voltage
	16 Watts at 125VDC Control Voltage

TIME DELAY RANGE

2 to 99 cycles in 1-cycle setting increments with a tolerance of better than $\pm 5\%$. The total minimum operating time of the relay is 4 cycles - 3 cycles of underfrequency detection and 1 cycle operating time for the trip relay. The timer will start after the first detected underfrequency cycle and, if set for 2 cycles of delay, will time out at the same time that tripping is enabled by the trip control logic.

* OPERATING TIME

The operating time for the SDF-1 relay, taken from the first positive-going zero crossing of the ac potential wave after the underfrequency set-point is crossed, is equal to the time delay set on the front panel decade switches plus 2 cycles. This is because one cycle is used by the period-checking circuitry to determine that an underfrequency condition exists before the timer can be started; also, the tripping relay requires one cycle to pick up after the time delay expires. Trip control logic will not allow tripping to take place until at least 3 underfrequency cycles have been detected, regardless of a lower time delay setting; the minimum total operating time is thus 4 cycles if trip relay pickup time is included.

Examples of SDF-1 timing are illustrated in the figures. Refer to figure 14. Note that the relay senses frequency by measuring the time between positive-going zero crossings. If the frequency is initially above the trip setting and then declines fairly linearly, as will occur in service, the relay will measure the average frequency over each cycle. Thus, it will detect the underfrequency condition during a given cycle only if the trip setting is crossed before that cycle is half-completed. Otherwise, detection will occur during the following cycle. The resultant timing variation is less than $\pm \frac{1}{2}$ cycle. In the example of figure 14, the relay has a delay setting of 6 cycles on the front panel decade switches. The total time from underfrequency set-point crossing to trip contact closure will be between 7.5 and 8.5 cycles, depending on the position of the ac wave when the frequency setting is crossed.

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(See Table I)

Increments of less than 0.05 Hz can be obtained if needed for unusual applications.

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The SDF-1 relay is designed to operate on either 48 or 125 volts d.c. with no settings or adjustments required. The operating range is 42 to 140 volts dc.

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The operating time for the SDF-1 relay, taken from the first positive-going zero crossing of the ac potential wave after the underfrequency set-point is crossed, is equal to the time delay set on the front panel decade switches plus 2 cycles. This is because one cycle is used by the period-checking circuitry to determine that an underfrequency condition exists before the timer can be started; also, the tripping relay requires one cycle to pick up after the time delay expires. Trip control logic will not allow tripping to take place until at least 3 underfrequency cycles have been detected, regardless of a lower time delay setting; the minimum total operating time is thus 4 cycles if trip relay pickup time is included.

Examples of SDF-1 timing are illustrated in the figures. Refer to figure 14. Note that the relay senses frequency by measuring the time between positive-going zero crossings. If the frequency is initially above the trip setting and then declines fairly linearly, as will occur in service, the relay will measure the average frequency over each cycle. Thus, it will detect the underfrequency condition during a given cycle only if the trip setting is crossed before that cycle is half-completed. Otherwise, detection will occur during the following cycle. The resultant timing variation is less than $\pm \frac{1}{2}$ cycle. In the example of figure 14, the relay has a delay setting of 6 cycles on the front panel decade switches. The total time from underfrequency set-point crossing to trip contact closure will be between 7.5 and 8.5 cycles, depending on the position of the ac wave when the frequency setting is crossed.

Now refer to figure 15. Suppose that ac is suddenly applied at a frequency below the trip setting, as might occur during bench testing of the relay, or possibly in the midst of a frequency disturbance. In this case there will be a delay of up to, but less than, one cycle before the SDF-1 starts to measure the underfrequency condition. This variable time is in addition to the trip delay setting plus 2 cycles. In the example, the time from energization to contact closure will be between 8 and 9 cycles.

TRIP CIRCUIT

The main contacts will close 30 amperes at 250 volts d-c and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker. The indicating contactor switch has two taps that provide a pickup setting of 0.2 or 2 amperes. To change taps requires connecting of the lead located in front of the tap block to the desired setting by means of a screw connection.

TRIP CIRCUIT CONSTANTS

Indicating Contactor Switch —

- 0.2 amp tap 6.5 ohms d-c resistance.
- 2.0 amp tap 0.15 ohms d-c resistance.

TEMPERATURE RANGE

The SDF-1 is designed to operate over a temperature range from -30°C to $+70^{\circ}\text{C}$.

SETTINGS

UNDERFREQUENCY TRIP POINT

The SDF-1 relay is set for underfrequency trip by the tap screws in the underfrequency trip point setting assembly on the front panel of the relay. The binary settings for frequencies from 60.00 to 54.00 Hz in 0.05 Hz steps are given in Table I. When the tap screw is in the "1" upper position it contributes to the frequency setting as in the following weighting table.

TABLE II

Underfrequency Set Point Position Weights											
Binary Code Position	A	B	C	D	E	F	G	H	J	K	L
Weight ("1" Position)	1	2	4	8	16	32	64	128	256	512	1024

When the tap screw is in the "0" lower position it contributes 0 to the weight. The tap screws must be firmly tightened by hand in either of the two positions. Note: A screwdriver may be used to tighten the tap screws but caution should be exercised not to exert too much pressure on the screws.

An illustrative example is the assumption that a tripping point of 59.50 Hz is desired. The tap screws should be fastened in the following combination according to Table I.

	A	B	C	D	E	F	G	H	J	K	L
1		X		X				X			
0	X		X		X	X	X		X	X	X

Settings in increments as fine as the accuracy of the relay are possible, if needed for an unusual application. A request for the binary setting for a frequency not listed in Table I (but between 54.0 and 60.0 Hz) can be made through the nearest Westinghouse sales office.

Selecting a Frequency Setting

For load-shedding, the frequency is normally set as high as possible without approaching the region of normal system frequency swings (usually set 59.5 Hz or below). High settings, combined with short time delay, will provide greatest protection from severe system overload (see "Selecting a Time Delay" in the following section). A number of relays may be set in successively lower steps for more selective load-saving.

Trip Time Delay Setting

The trip time delay is set in 1-cycle increments with the decade switches on the front panel from the minimum of 2 cycles to 99 cycles (60 Hz base). The delay settings of the two controls are additive. A delay of less than 2 cycles is not possible because of trip control logic (as explained in "Theory of Operation"); setting below 2 cycles will be of no benefit. The timer will start after the first underfrequency cycle is recognized; the combined presence of outputs from the timer and from the trip control logic (indicating 3 consecutive under-

frequency cycles) will enable tripping. The closing of the trip relay contact will require one additional cycle after the time delay has elapsed.

Note that the cycle calibrations assume a 60 Hz reference (i.e., one cycle equals 16.67 ms). The time delay is an analog function, unrelated to the ac input cycles.

Selecting a Time Delay

When a system overload occurs, underfrequency relays must disconnect load to arrest frequency decline. The output of generating plants may be impaired below 57-57.5 Hz, so shedding must be completed before this level is reached. Shortest possible time delay is usually advantageous. Note that, due to the frequency-checking technique of the SDF-1 relay, no intentional time delay is required to avoid misoperation for transients of short duration (such as phase-angle shifts due to fault inception or clearing). However, time delay may be used to prevent response to misleading inputs (such as line excitation by a slowing motor load); or, in some schemes, to coordinate a number of relays set to the same frequency.

Fig. 13 shows the effect of time delay on the actual frequency at which tripping takes place under declining frequency conditions. The curves show how the frequency continues to drop in the time interval required for the relay to operate after its frequency set-point is crossed.

For example, suppose that for a system of inertia constant $H = 2$, it is required that the frequency not dip below 57.5 Hz for any overload up to 46%. Assume the relay is set to trip at 59.20 Hz. The scale at the bottom of figure 13 indicates that a 46% overload will cause a 6 Hz/sec rate of decline. According to Figure 13, the SDF-1 relay with 15 cycles of delay setting will close its trip contact when the frequency has dropped 1.7 Hz below the set point, or 57.5 Hz, for this overload condition. Thus, 15 cycles is the maximum acceptable time delay setting to obtain the desired protection.

Now suppose the relay trips a 5-cycle breaker. Since load must actually be disconnected to arrest frequency decline, the breaker operating time has the same effect as additional time delay setting. Because 15 cycles is the longest tolerable delay, the relay should not have more than 10 cycles of delay setting.

The curves in Figure 13 have been plotted to include the effect of the delay setting, as labeled on each curve, along with two additional cycles for initial underfrequency detection and telephone relay operation. Thus, the curve corresponding to 2 cycles of delay setting is plotted for 4 cycles total SDF-1 operating time, etc. Use the curve whose label corresponds to the actual setting of the decade switches.

INDICATING CONTACTOR SWITCH (ICS)

The only setting of the ICS unit required is the selection of the .2 or 2 ampere pick-up tap. This accomplished by connecting the lead located in front of the tap block to the desired terminal by means of a connecting screw.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the mounting stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench. See Fig. 14 for Outline and Drilling plan.

For detailed information on the FT case, refer to I.L. 41-076.

ADJUSTMENTS & MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory. Upon receipt of the relay no customer adjustments, other than those covered under "SETTINGS" should be required.

ACCEPTANCE CHECK

It is recommended that an acceptance check be applied to the SDF-1 relay to verify that the circuits are functioning properly.

The following procedure can be used for this purpose.

1. Settings

Check front panel settings; they should be as follows:

- a. Underfrequency trip point desired set on the underfrequency trip point setting assembly as per Table I.
- b. Trip time delay set for the desired cycles delay on the trip time delay decade setting knobs.

2. Indicating Contactor Switch

Close the trip relay contacts and pass sufficient d-c current through the trip circuit (Relay terminals 1 and 10) to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

3. Underfrequency Trip Point Setting

Connect SDF-1 Relay per test diagram Figure 10. Using a variable frequency source apply 120 volts at set tripping frequency. Relay should trip within $\pm .007$ Hz of set trip frequency in the time set on the digital trip time delay setting plus 16 milliseconds operating time of the trip relay. Raise frequency of source above the trip point setting (.007 Hz. or higher) and the trip relay should drop out after approximately two cycles delay.

4. Undervoltage Detector

Lower frequency of source so relay once again trips; lower voltage of source below 25 volts, and the trip relay should drop out.

5. Test Module 204C299G01 (Optional)

Test module 204C299G01 may be utilized to test the underfrequency trip setting of the SDF-1 relay. When inserted into its relay connector and test points T8 and T9 on module 204C261G01 are connected together, underfrequency trip point settings may be checked by switching the same binary number on the test module that is set on the underfrequency trip point setting assembly to trip the relay. Likewise, dropping the test module setting down by a weight of one or greater (see Table II), corresponding to a higher frequency, will allow the relay to reset.

ROUTINE MAINTENANCE

All relays should be checked at least once every year or at such other intervals as may be dictated

by experience to be suitable to the particular application.

CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments have been disturbed. This procedure should not be used unless it is apparent that the relay is not in proper working order. (See "Acceptance Check").

INDICATING CONTACTOR SWITCH (ICS)

Close the trip relay contacts and pass sufficient d-c current through the trip circuit (Relay terminals 1 and 10) to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

The contact gap should be approximately .047" between the bridging moving contact and the adjustable stationary contact. The bridging moving contact should touch both stationary contacts simultaneously.

D.C. REGULATED SUPPLIES

The 18 volt d-c. supply should be adjusted by potentiometer R81 on power supply module 204C265G01 for 18 volts $\pm 1\%$ at 125 VDC battery voltage. The 5 volt d-c. supply should then be within $\pm 5\%$. Both regulated supplies should maintain their respective voltages $\pm 5\%$ with a battery range of 42 to 140 volts d.c.

MAIN CLOCK ADJUSTMENT

Inductor L-1 should be adjusted to obtain the correct clock signal CPO at TP2 on module 204C262G01. The correct signal is 1.966080 MHz. with a tolerance range of 1.965980 MHz. to 1.966180 MHz.

UNDERFREQUENCY TRIP TEST

Connect the SDF-1 Relay per test diagram Figure 10. Using a variable frequency source apply 120 volts at set tripping frequency. Relay should trip within ± 0.007 Hz. of set trip frequency in the time set on the trip time delay setting plus 16 milliseconds operating time of the trip relay. Raise frequency of source 0.007 Hz or higher above the trip point setting and the trip relay should drop out after approximately two cycles delay.

TRIP CONTROL CIRCUIT AND DELAY TIMER ADJUSTMENT

Potentiometer R46 on module 204C264G01 must be adjusted to bring the 99 cycle delay setting to 99 cycles (60 Hz base), i.e., 1.650 seconds. Remember that the total operating time is equal to the delay setting plus 2 additional cycles. Thus, at 99 cycles delay setting the potentiometer R46 should be set so that the total operating time is 101 cycles or 1.683 seconds. The delay timer should be tested at each position on the selector switch. (Note: Delay settings for 1 or 2 cycles will give the minimum delay of 2 cycles and can only be checked at a higher setting: i.e. 1 cycle has to be checked at 11 cycles delay setting, or 21, 31, etc.).

TEST MODULE 204C299G01 (Optional)

Test module 204C299G01 may be utilized to test

the underfrequency trip setting of the SDF-1 relay. When inserted into its relay connector and test points T8 and T9 on module 204C261G01 are connected together, underfrequency trip point settings (Table I) may be checked by switching the same binary number on the test module that is set on the underfrequency trip point setting assembly to trip the relay. Likewise, dropping the test module setting down by a weight of one or greater (see Table II), corresponding to a higher frequency, will allow the relay to reset.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

TABLE I

FREQ. (HZ)	PERIOD (MS)	UNDERFREQUENCY TRIP POINT SETTING											FREQ. (HZ)	PERIOD (MS)	UNDERFREQUENCY TRIP POINT SETTING										
		A	B	C	D	E	F	G	H	J	K	L			A	B	C	D	E	F	G	H	J	K	L
60.00	16.6667	0	0	0	0	0	0	0	0	0	0	0	58.50	17.0940	0	0	1	0	0	1	0	1	1	0	0
59.95	16.6806	0	1	1	1	0	0	0	0	0	0	0	58.45	17.1086	0	1	0	0	1	1	0	1	1	0	0
59.90	16.6945	1	1	0	1	1	0	0	0	0	0	0	58.40	17.1233	1	0	0	0	0	0	1	1	1	0	0
59.85	16.7084	1	0	0	1	0	1	0	0	0	0	0	58.35	17.1380	1	1	1	1	0	0	1	1	1	0	0
59.80	16.7224	1	1	1	0	1	1	0	0	0	0	0	58.30	17.1527	0	1	1	1	1	0	1	1	1	0	0
59.75	16.7364	1	0	1	0	0	0	1	0	0	0	0	58.25	17.1674	0	0	1	1	0	1	1	1	1	0	0
59.70	16.7504	0	1	0	0	1	0	1	0	0	0	0	58.20	17.1821	1	1	0	1	1	1	1	1	1	0	0
59.65	17.7645	0	0	0	0	0	1	1	0	0	0	0	58.15	17.1969	1	0	0	1	0	0	0	0	0	1	0
59.60	16.7785	0	1	1	1	0	1	1	0	0	0	0	58.10	17.2117	0	0	0	1	1	0	0	0	0	1	0
59.55	16.7926	0	0	1	1	1	1	1	0	0	0	0	58.05	17.2265	0	1	1	0	0	1	0	0	0	1	0
59.50	16.8067	0	1	0	1	0	0	0	1	0	0	0	58.00	17.2414	1	0	1	0	1	1	0	0	0	1	0
59.45	16.8209	0	0	0	1	1	0	0	1	0	0	0	57.95	17.2563	0	0	1	0	0	0	1	0	0	1	0
59.40	16.8350	1	0	1	0	0	1	0	1	0	0	0	57.90	17.2712	0	1	0	0	1	0	1	0	0	1	0
59.35	16.8492	1	1	0	0	1	1	0	1	0	0	0	57.85	17.2861	1	0	0	0	0	1	1	0	0	1	0
59.30	16.8634	1	0	0	0	0	0	1	1	0	0	0	57.80	17.3010	0	0	0	0	1	1	1	0	0	1	0
59.25	16.8776	1	1	1	1	0	0	1	1	0	0	0	57.75	17.3160	0	1	1	1	1	1	1	0	0	1	0
59.20	16.8919	1	0	1	1	1	0	1	1	0	0	0	57.70	17.3310	1	0	1	1	0	0	0	1	0	1	0
59.15	16.9062	1	1	0	1	0	1	1	1	0	0	0	57.65	17.3461	0	0	1	1	1	0	0	1	0	1	0
59.10	16.9205	0	1	0	1	1	1	1	1	0	0	0	57.60	17.3611	1	1	0	1	0	1	0	1	0	1	0
59.05	16.9348	0	0	0	1	0	0	0	0	1	0	0	57.55	17.3762	1	0	0	1	1	1	0	1	0	1	0
59.00	16.9492	0	1	1	0	1	0	0	0	1	0	0	57.50	17.3913	0	0	0	1	0	0	1	1	0	1	0
58.95	16.9635	0	0	1	0	0	1	0	0	1	0	0	57.45	17.4064	1	1	1	0	1	0	1	1	0	1	0
58.90	16.9779	0	1	0	0	1	1	0	0	1	0	0	57.40	17.4216	0	1	1	0	0	1	1	1	0	1	0
58.85	16.9924	0	0	0	0	0	0	1	0	1	0	0	57.35	17.4368	1	0	1	0	1	1	1	1	0	1	0
58.80	17.0068	0	1	1	1	0	0	1	0	1	0	0	57.30	17.4520	0	0	1	0	0	0	0	0	1	1	0
58.75	17.0213	1	0	1	1	1	0	1	0	1	0	0	57.25	17.4672	1	1	0	0	1	0	0	0	1	1	0
58.70	17.0358	1	1	0	1	0	1	1	0	1	0	0	57.20	17.4825	0	1	0	0	0	1	0	0	1	1	0
58.65	17.0503	1	0	0	1	1	1	1	0	1	0	0	57.15	17.4978	1	0	0	0	1	1	0	0	1	1	0
58.60	17.0648	1	1	1	0	0	0	0	1	1	0	0	57.10	17.5131	0	0	0	0	0	0	1	0	1	1	0
58.55	17.0794	0	1	1	0	1	0	0	1	1	0	0	57.05	17.5285	1	1	1	1	0	0	1	0	1	1	0

TABLE I (Cont.)

FREQ. (HZ)	PERIOD (MS)	UNDERFREQUENCY TRIP POINT SETTING											FREQ. (HZ)	PERIOD (MS)	UNDERFREQUENCY TRIP POINT SETTING										
		A	B	C	D	E	F	G	H	J	K	L			A	B	C	D	E	F	G	H	J	K	L
57.00	17.5439	0	1	1	1	1	0	1	0	1	1	0	55.50	18.0180	0	0	0	0	1	1	0	0	1	0	1
56.95	17.5593	1	0	1	1	0	1	1	0	1	1	0	55.45	18.0343	0	0	0	0	0	0	1	0	1	0	1
56.90	17.5747	1	0	1	1	1	1	1	0	1	1	0	55.40	18.0505	0	0	0	0	1	0	1	0	1	0	1
56.85	17.5901	0	0	1	1	0	0	0	1	1	1	0	55.35	18.0668	0	0	0	0	0	1	1	0	1	0	1
56.80	17.6056	1	1	0	1	1	0	0	1	1	1	0	55.30	18.0832	0	0	0	0	1	1	1	0	1	0	1
56.75	17.6211	0	1	0	1	0	1	0	1	1	1	0	55.25	18.0995	1	0	0	0	0	0	0	1	1	0	1
56.70	17.6367	0	1	0	1	1	1	0	1	1	1	0	55.20	18.1159	1	0	0	0	1	0	0	1	1	0	1
56.65	17.6523	1	0	0	1	0	0	1	1	1	1	0	55.15	18.1324	1	0	0	0	0	1	0	1	1	0	1
56.60	17.6678	0	0	0	1	1	0	1	1	1	1	0	55.10	18.1488	1	0	0	0	1	1	0	1	1	0	1
56.55	17.6835	0	0	0	1	0	1	1	1	1	1	0	55.05	18.1653	1	0	0	0	0	0	1	1	1	0	1
56.50	17.6991	1	1	1	0	1	1	1	1	1	1	0	55.00	18.1818	1	0	0	0	1	0	1	1	1	0	1
56.45	17.7148	0	1	1	0	0	0	0	0	0	0	1	54.95	18.1984	0	1	0	0	0	1	1	1	1	0	1
56.40	17.7305	0	1	1	0	1	0	0	0	0	0	1	54.90	18.2149	0	1	0	0	1	1	1	1	1	0	1
56.35	17.7462	1	0	1	0	0	1	0	0	0	0	1	54.85	18.2315	0	1	0	0	0	0	0	0	0	1	1
56.30	17.7620	1	0	1	0	1	1	0	0	0	0	1	54.80	18.2482	1	1	0	0	1	0	0	0	0	1	1
56.25	17.7778	0	0	1	0	0	0	1	0	0	0	1	54.75	18.2648	1	1	0	0	0	1	0	0	0	1	1
56.20	17.7936	0	0	1	0	1	0	1	0	0	0	1	54.70	18.2815	1	1	0	0	1	1	0	0	0	1	1
56.15	17.8094	1	1	0	0	0	1	1	0	0	0	1	54.65	18.2983	0	0	1	0	0	0	1	0	0	1	1
56.10	17.8253	1	1	0	0	1	1	1	0	0	0	1	54.60	18.3150	0	0	1	0	1	0	1	0	0	1	1
56.05	17.8412	1	1	0	0	0	0	0	1	0	0	1	54.55	18.3318	1	0	1	0	0	1	1	0	0	1	1
56.00	17.8571	0	1	0	0	1	0	0	1	0	0	1	54.50	18.3486	1	0	1	0	1	1	1	0	0	1	1
55.95	17.8731	0	1	0	0	0	1	0	1	0	0	1	54.45	18.3655	0	1	1	0	0	0	0	1	0	1	1
55.90	17.8891	0	1	0	0	1	1	0	1	0	0	1	54.40	18.3824	1	1	1	0	1	0	0	1	0	1	1
55.85	17.9051	1	0	0	0	0	0	1	1	0	0	1	54.35	18.3993	1	1	1	0	0	1	0	1	0	1	1
55.80	17.9211	1	0	0	0	1	0	1	1	0	0	1	54.30	18.4162	0	0	0	1	1	1	0	1	0	1	1
55.75	17.9372	1	0	0	0	0	1	1	1	0	0	1	54.25	18.4332	1	0	0	1	0	0	1	1	0	1	1
55.70	17.9533	1	0	0	0	1	1	1	1	0	0	1	54.20	18.4502	1	0	0	1	1	0	1	1	0	1	1
55.65	17.9695	1	0	0	0	0	0	0	0	1	0	1	54.15	18.4672	0	1	0	1	0	1	1	1	0	1	1
55.60	17.9856	1	0	0	0	1	0	0	0	1	0	1	54.10	18.4843	1	1	0	1	1	1	1	1	0	1	1
55.55	18.0018	0	0	0	0	0	1	0	0	1	0	1	54.05	18.5014	0	0	1	1	0	0	0	0	1	1	1
													54.00	18.5185	0	0	1	1	1	0	0	0	1	1	1

ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
RESISTORS		
R1	68 K ohm 5% ½ W.	184A763H71
R2	4.3 K ohm 5% ½ W.	184A763H42
R3, R3, R7, R16, R30, R32, R41	3 K ohm 5% ½ W.	184A763H38
R5, R64, R68	5.1 K ohm 5% ½ W.	184A763H44
R6, R33, R71	1.8 K ohm 5% ½ W.	184A763H33
R8	3.3 K ohm 5% ½ W.	184A763H39
R9	3.57 K ohm 1% ½ W.	862A376H54
R10	1.78 K ohm 1% ½ W.	862A376H25
R11, R13, R55, R72	2.43 K ohm 1% ½ W.	862A376H38
R12, R86	15 K ohm 5% ½ W.	184A763H55
R14, R67	1.1 K ohm 1% ½ W.	862A376H05
R15	20 K ohm 1% ½ W.	862A377H30
R17	9.1 K ohm 5% ½ W.	184A763H50
R18	1.5 K ohm 5% ½ W.	184A763H31
R19, R20	22.1 K ohm 1% ½ W.	862A377H34
R21, R22, R23, R24	2 K ohm 5% 3W.	763A127H03 *
R25	2.7 K ohm 5% ½ W.	184A763H37
R26, R27	1.2 K ohm 5% ½ W.	184A763H29
R28	56 K ohm 5% ½ W.	184A763H69
R29, R39, R79	5.6 K ohm 5% ½ W.	184A763H45
R31, R38	2.4 K ohm 5% ½ W.	184A763H36
R34, R37	330 ohm 5% ½ W.	184A763H15
R35, R36, R61	300 K ohm 5% ½ W.	184A763H86
R40	2.2 K ohm 5% ½ W.	184A763H35
R42	120 ohm 5% ½ W.	184A763H05
R43	75 K ohm 5% ½ W.	184A763H72
R45	11 K ohm 1% ½ W.	862A377H05
R46	2 K ohm 10% ½ W.	862A406H01
R47	1.87 K ohm 1% ½ W.	862A376H27
R50	49.9 ohm 1% ½ W.	862A374H68
R51, R56, R58	3 K ohm 5% ½ W.	184A763H38
R52	39 K ohm 5% ½ W.	184A763H65
R53	27 K ohm 5% ½ W.	184A763H61
R54	2.21 K ohm 1% ½ W.	862A376H34
R57	10 K ohm 5% ½ W.	184A763H51
R59	10 ohm 5% 25 W.	04D1297H27
R60	68 K ohm 5% 1 W.	187A643H71
R62	8.2 K ohm 5% ½ W.	184A763H49
R63	100 K ohm 5% ½ W.	184A763H75
R65	10 Megohm 5% ½ W.	187A290H27
R66	301 ohm 1% ½ W.	862A375H47
R69	1.21 K ohm 1% ½ W.	862A376H09
R70, R74	200 ohm 5% ½ W.	184A763H10
R73, R89	1 K ohm 1% ½ W.	862A376H01
R75	47.5 K ohm 1% ½ W.	862A377H66
R76	3.92 K ohm 1% ½ W.	862A376H58
R77	1 ohm 5% 2 W.	187A683H25

ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
RESISTORS (Continued)		
R78	2.74K ohm 1% 1/2 W.	862A376H43
R80	10 ohm 5% 1/2 W.	187A290H01
R81	500 ohm 10% 1 W.	837A166H01
R82	392 ohm 1% 1/2 W.	862A375H58
R83, R85, R87	1.62K ohm 1% 1/2 W.	862A376H21
R84	619 ohm 1% 1/2 W.	862A375H77
R88	120 ohm 5% 3 W.	763A127H21
R90, R91, R92, R93, R94, R94, R96, R97, R98	1.21K ohm 1% 1/2 W.	848A829H56
R100, R101, R102, R103, R104, R105, R106, R107, R108	12.1 K ohm 1% 1/2 W.	848A820H53
CAPACITORS		
C1, C16, C20, C29, C30, C31	.47 MFD. 50V. 20%	762A680H04
C2, C8, C11, C28	.1 MFD 100V. 10%	836A620H03
C3, C5, C24	.47 MFD 200V. 10%	188A669H01
C4	100 PFD 200V. 10%	836A620H01
C6, C7	50 PFD 500V. 2%	187A695H15
C9	30 PFD 500V. 2%	187A695H09
C10	.018 MFD 100V 10%	836A620H04
C12	500 PFD 500V	184A663H05
C13	51 PFD 500V 2%	187A695H16
C14	250 PFD 500V 2%	187A695H33
C15, C17, C19	100 PFD 1000V	184A663H06
C18	8 MFD 30V 5%	862A177H07
C22	1.0 MFD 200V 20%	876A409H10
C23	.47 MFD 100V 5%	876A409H02
C25	75 PFD 500V 2%	187A695H20
C26	.01 MFD 50V 10%	836A620H05
C27	5.0 MFD 100V 20%	763A219H12
C32	1.0 MFD 200V 20%	876A409H10
DIODES		
D1, D2, D7, D8, D10, D12, D13, D14, D15, D16, D17, D19, D21 D22, D23, D27, D28, A, B, C, D, E, F, G, H, J, K, L, D3, D4, D5, D6	1N4148	878A649H01
D9, D11	1N645	184A855H13
D18	1N457	184A855H15
D20	338D	837A398H07
D24, D25	1N457A	184A885H07
D26	1N5400	188A342H17
	MR842	878A648H01
ZENER DIODES		
Z1, Z7	1N747A	837A398H08
Z2	1N965E	186A797H08
Z3	1N962B	837A398H09
Z4, Z8, Z9	1N753A	862A606H01
Z5	1N971	862A606H04
Z6	1N974	186A797H14
Z10	HW22B	185A212H16
Z11	1N957B	186A797H06
Z12	1R200	629A369H01

ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
TRANSISTORS		
Q1, Q2, Q3, Q5, Q7, Q9, Q11, Q12, Q13, Q15, Q20, Q21, Q24, Q25 Q4, Q6, Q10, Q16, Q19, Q22, Q26, Q29 Q8 Q14, Q17 Q18 Q23 Q27 Q28	2N2219A 2N2905A 2N4222 D13T1 2N3440 2N5415 2N3055 DTS410	762A672H11 762A672H10 878A577H01 878A289H01 762A672H08 762A672H09 187A673H08 187A673H09
INTEGRATED CIRCUITS		
IQ4 A, Q, V, W B, K, L, R, S, T, U C, D, E, F, I, J, P G, H Counter Bits 0-1, 2-3, 4-5, 6-7, 8-9, 10-11, 12-13, 14-15 Trip 1-2	CA3026 U6A993059X U6A994659X U6A993259X U6A993659X U6A909959X	717B205H01 204C328H04 204C328H03 204C328H01 204C328H02 204C331H01
TRANSFORMERS - INDUCTORS		
T1 L1 L2	Input Isolation Transformer Inductor Inductor	878A574H01 878A654H01 878A562G01
MISCELLANEOUS		
TR CL1	Trip Relay Crystal	541D514H02 187A857H23
TEST MODULE 204C299G01 (OPTIONAL)		
R1 C1 C2 C3 D1 to D11 A B C SWITCH	120 ohm 5% ½ W. .47 MFD 35V 20% 100 PFD 200V 10% .1 MFD 100V 10% 1N4148 U6A993059X U6A994659X U6A993259X (11 Req'd)	184A763H05 187A508H05 836A620H01 836A620H03 878A469H01 204C328H04 204C328H03 204C328H01 878A645H01

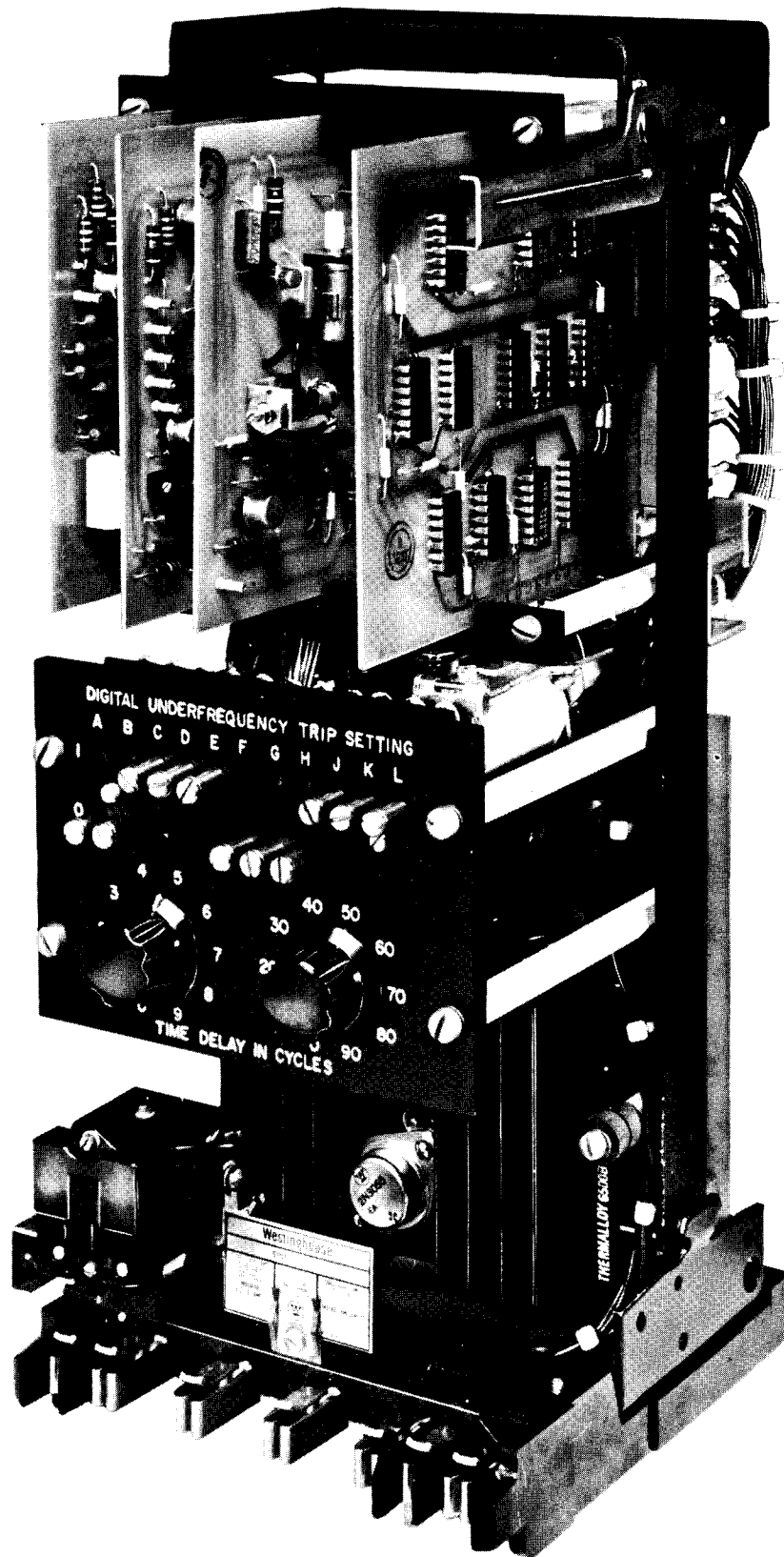


Fig. 1 Type SDF-1 Underfrequency Relay Front View (Without Case)

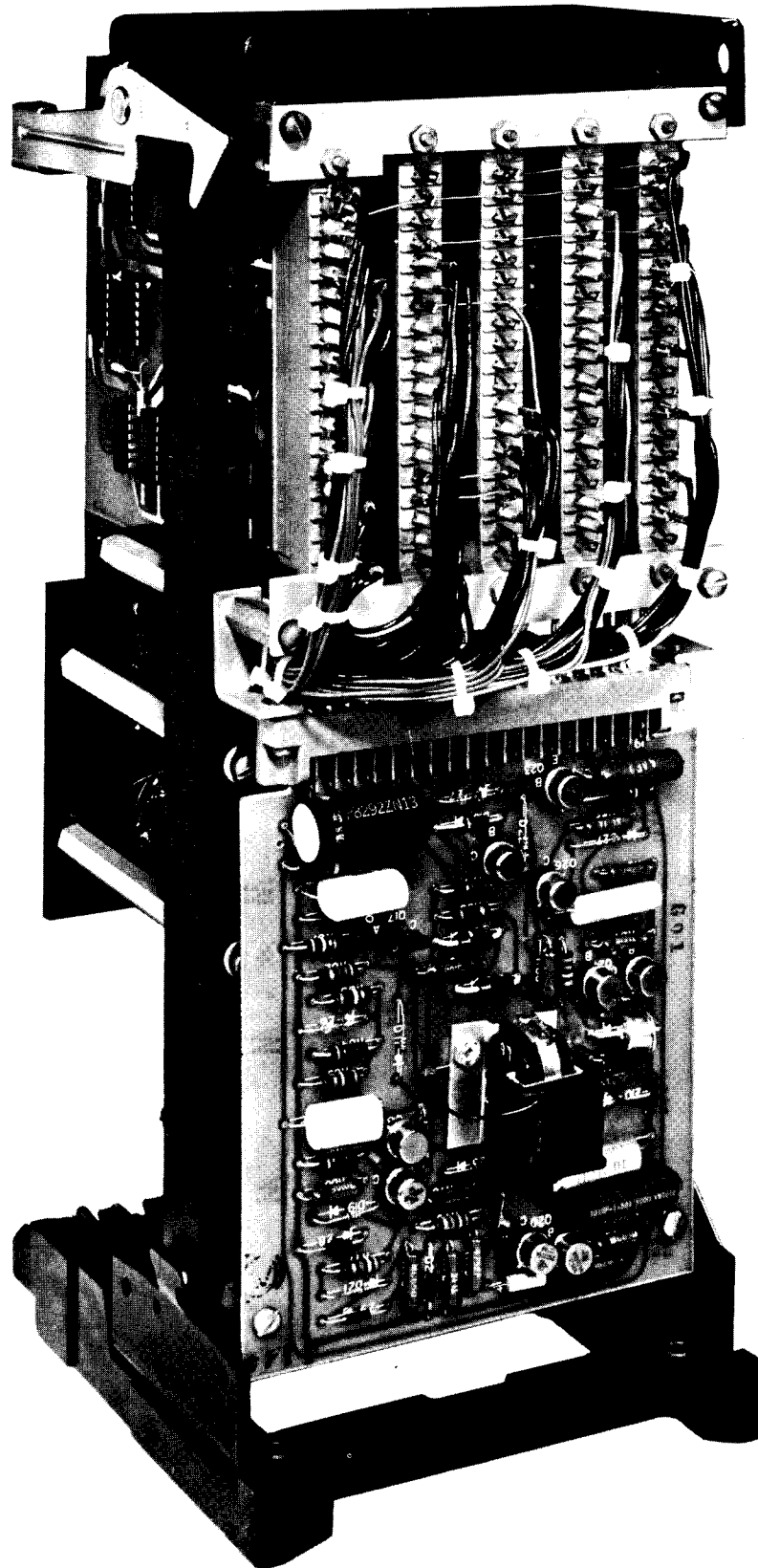


Fig. 2 Type SDF-1 Underfrequency Relay Rear View (Without Case)

TYPE SDF-1 SOLID STATE UNDERFREQUENCY RELAY

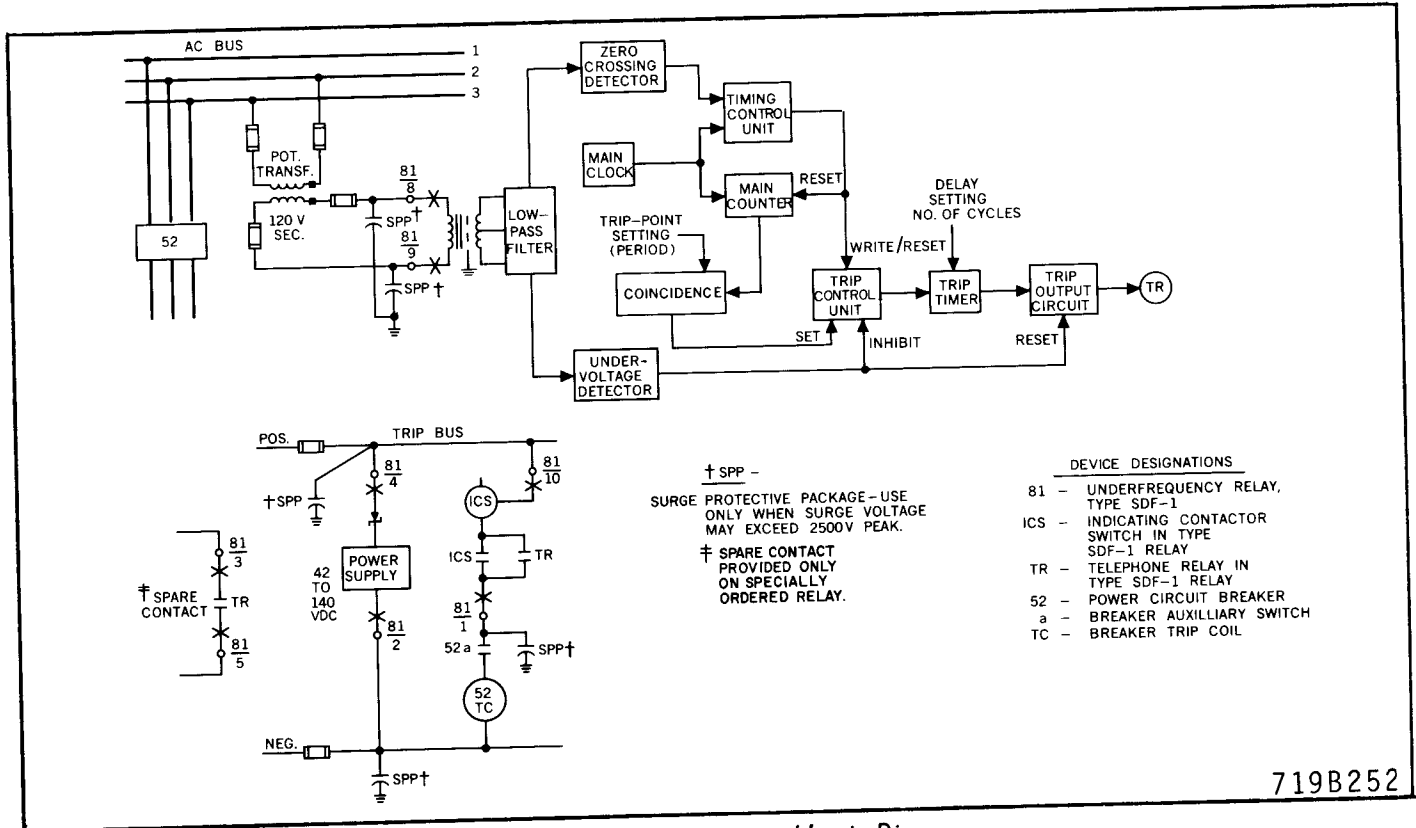


Fig. 4 External Schematic and Logic Diagram

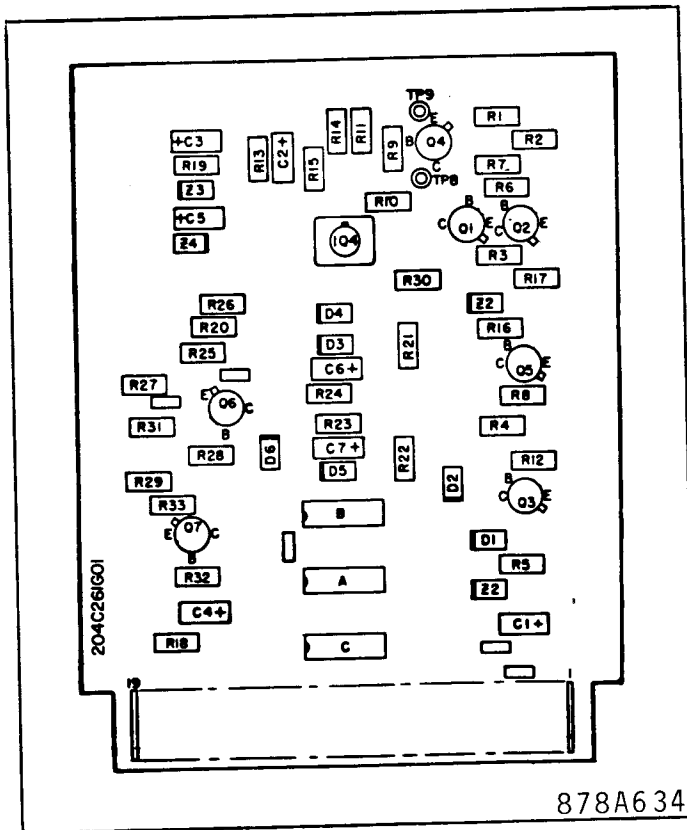


Fig. 5 Zero Crossing, Voltage Detectors, and Synchronizer Printed Circuit Module Component Location

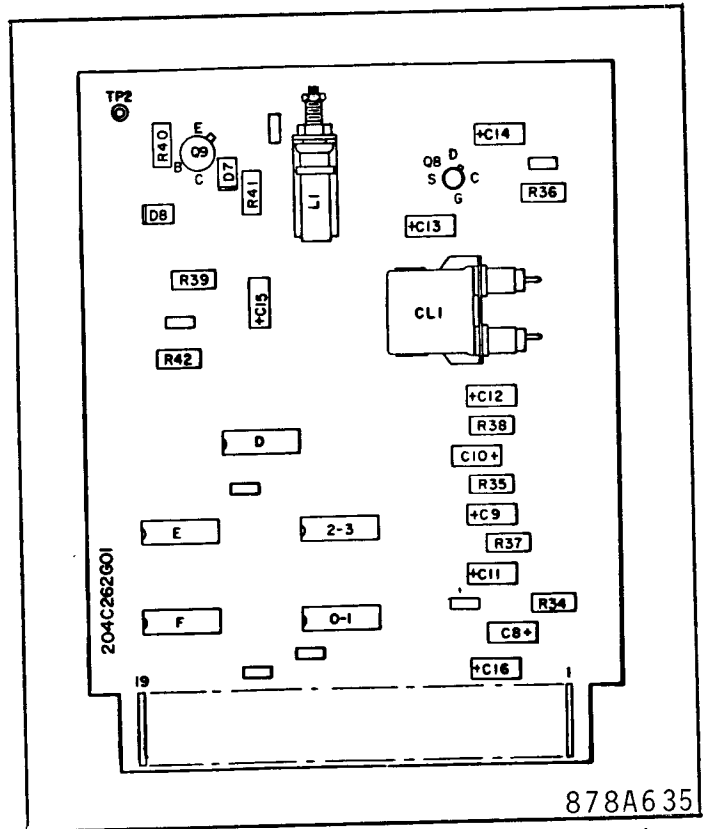


Fig. 6 Main Clock and Four Bit Binary Counter Printed Circuit Module Component Location

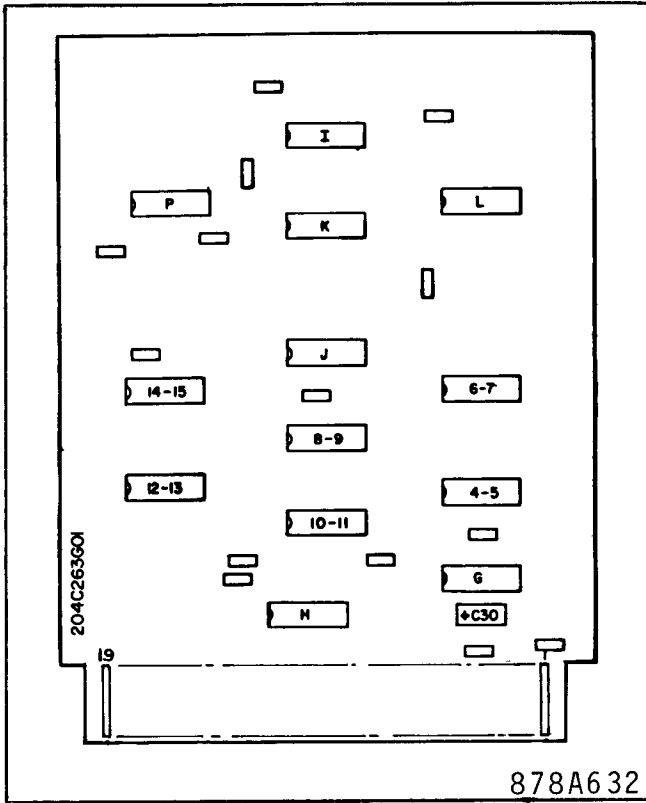


Fig. 7 Twelve Bit Binary Counter Printed Circuit Module Component Location

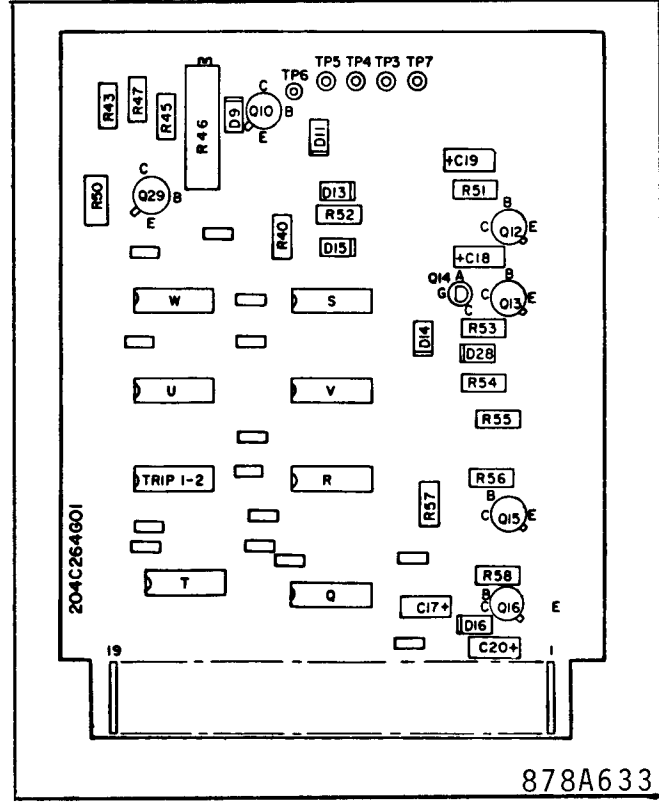


Fig. 8 Trip Control Circuit and Delay Timer Printed Circuit Module Component Location

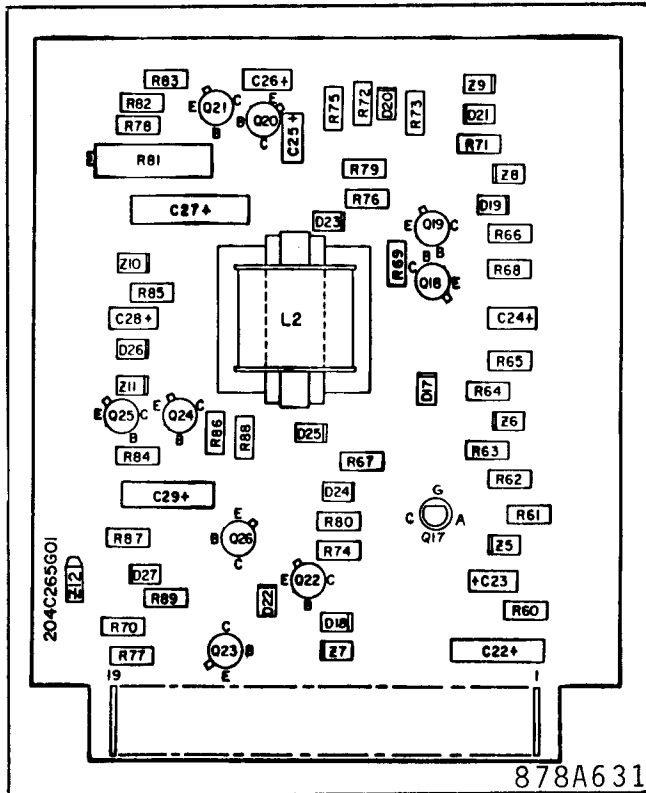


Fig. 9 Power Supply Printed Circuit Module Component Location

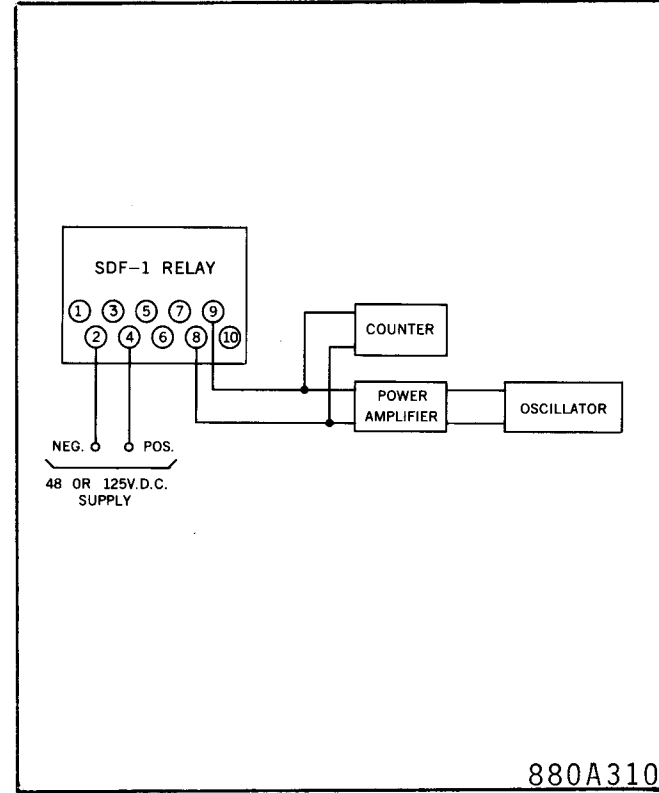
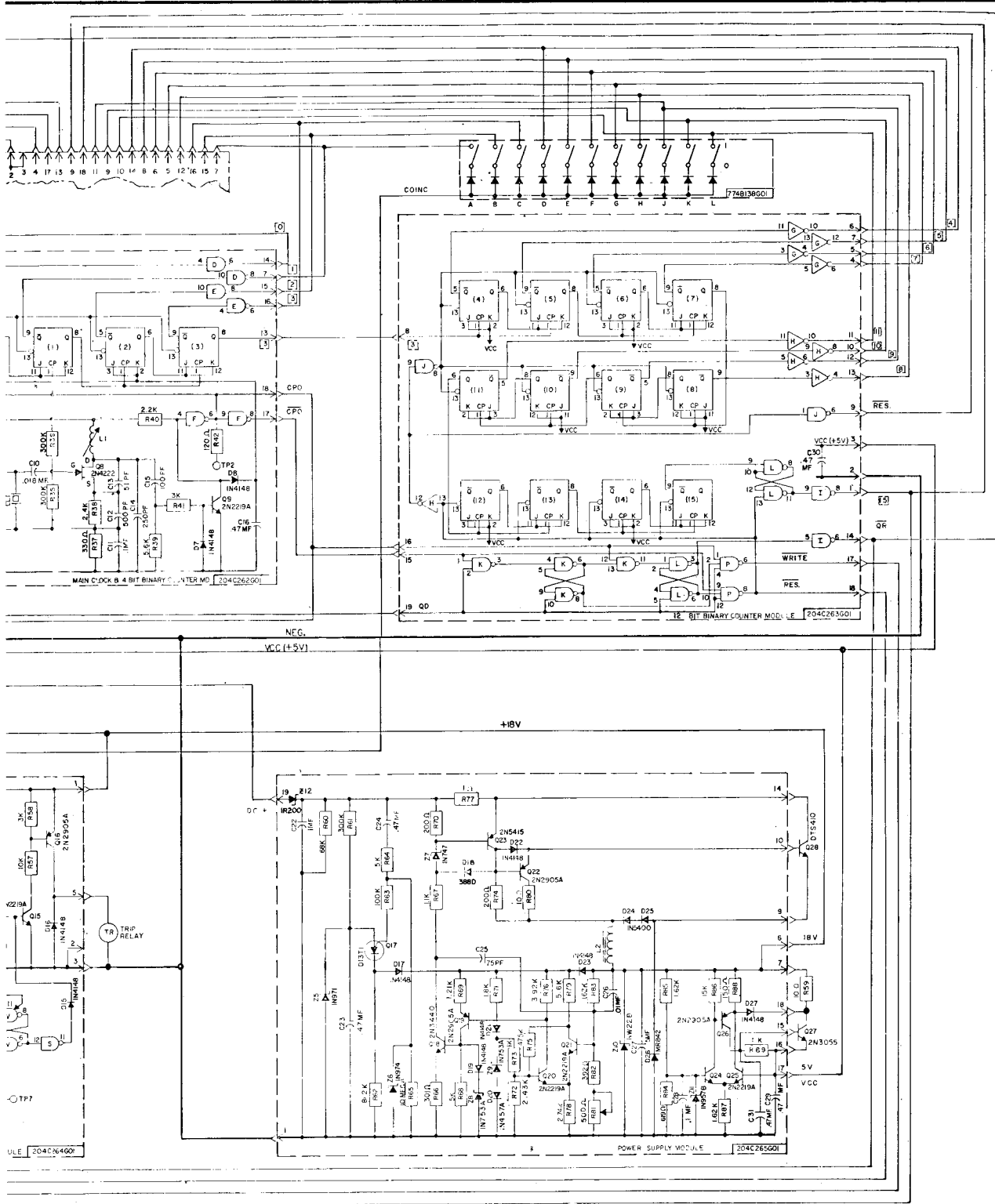


Fig. 10 Diagram of Test Connections for SDF-1 Relay



633F554

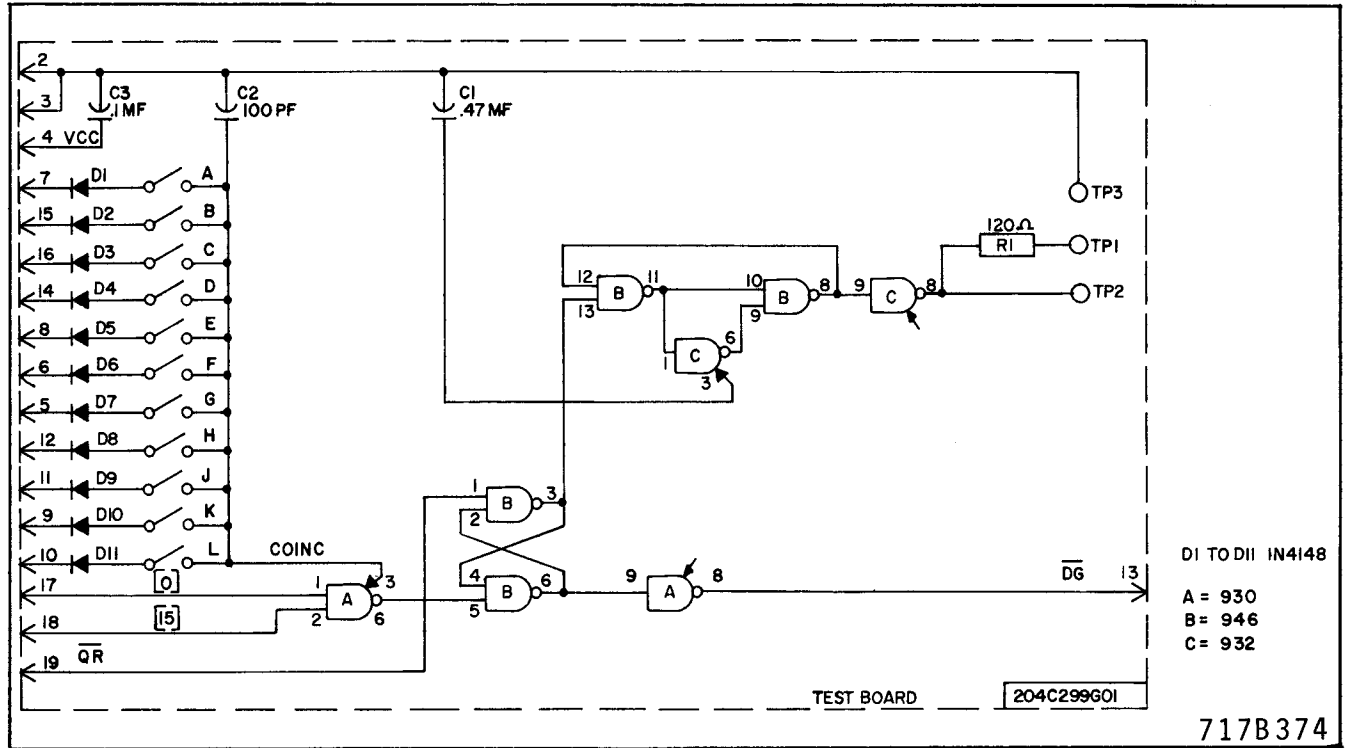


Fig. 11 Test Module Internal Schematic (Optional)

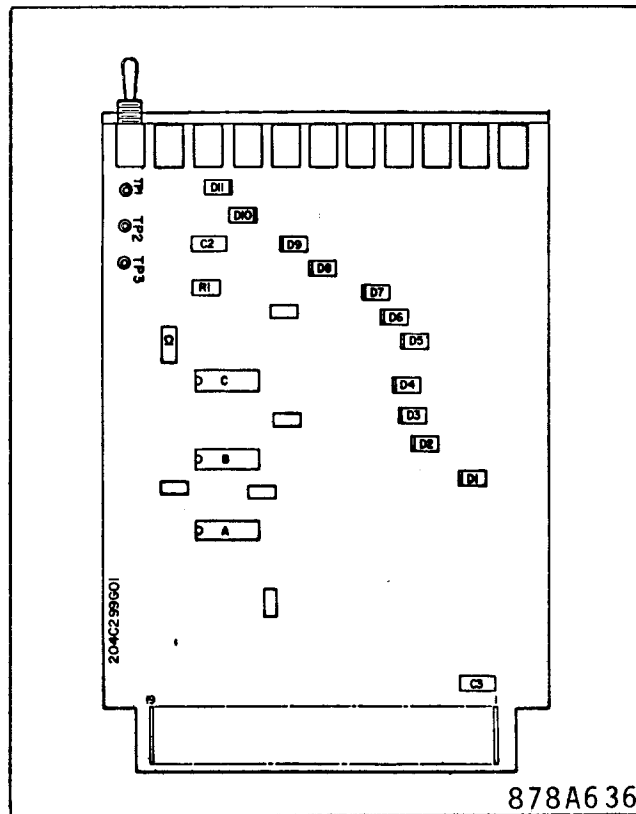


Fig. 12 Test Module Component Location

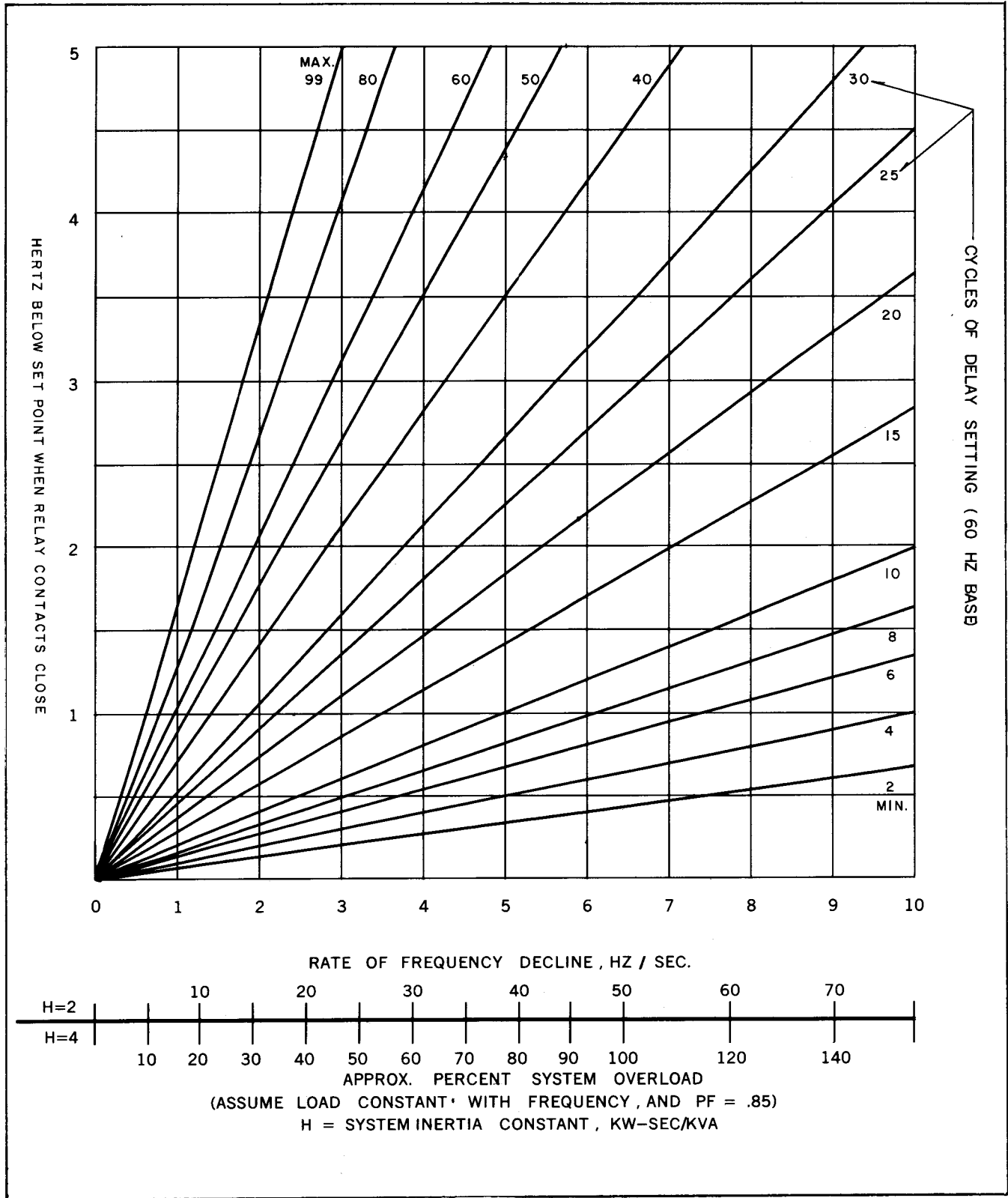
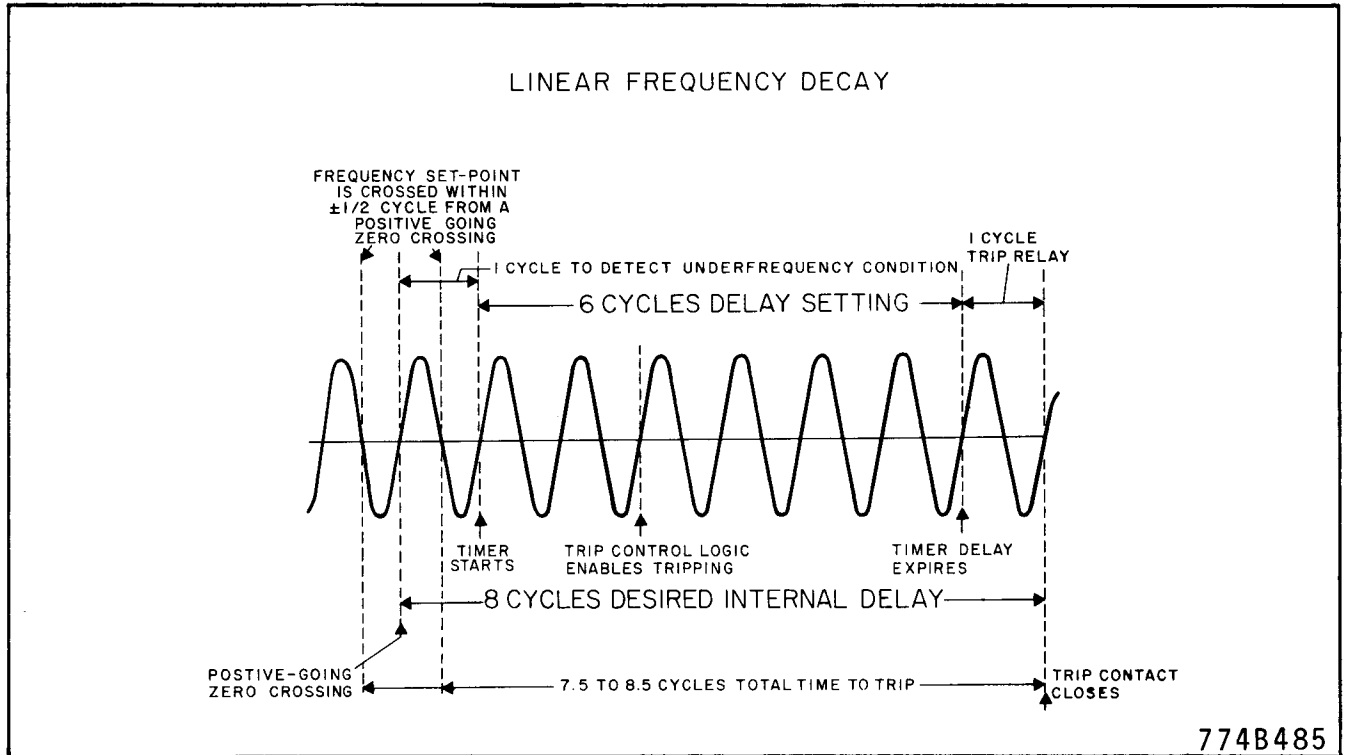
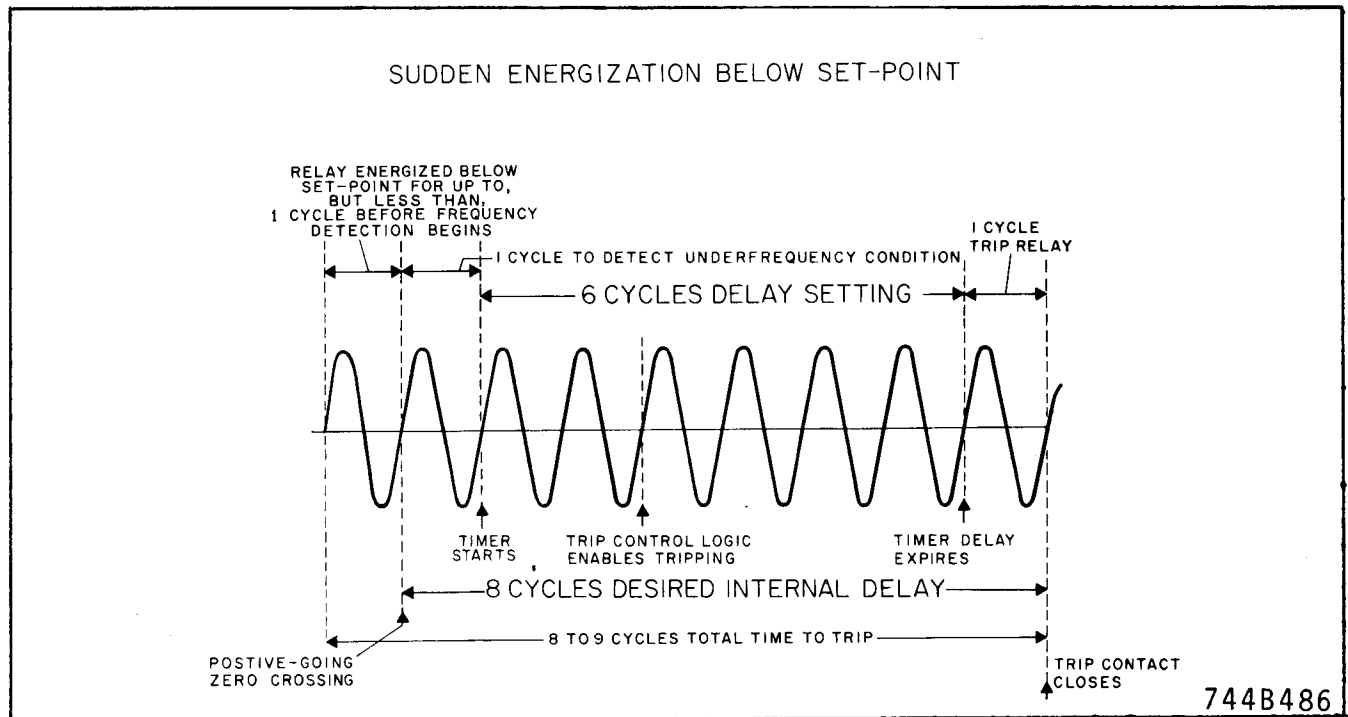


Fig. 13 SDF-1 Relay Tripping Delay Under Declining Frequency Conditions



* Fig. 14 Linear Frequency Decay



* Fig. 15 Sudden Energization Below Set-Point

