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MANUAL H-886

OPERATION & MAINTENANCE MANUAL

FOR

SFR-59 UNDERFREQUENCY RELAYS

P/N 7062501 - 7062509

P/N 7062561

P/N 7062570

*Note*  
*1973 version in next section*

Revised April, 1983

SUPPLEMENT

SFR-59-12A UNDERFREQUENCY RELAY

This relay has been specially modified from a standard Under-frequency Relay.

The modification consists of changing the trip duty output relay, K203, to a special output relay that provided two single pole, double throw output contacts rated as follows:

Make	2A at 150V dc
Carry	2A at 150V dc
Open	0.1A at 150V dc

Also, the normal seal-in feature has been eliminated. The target operation is as described in the manual except the target only indicates that the current relay has been energized.

The following drawings are to be used for the Relay:

Schematic 7265420 replaces 7265401  
Int/Ext Wiring Diagram 7253409 replaces 7253401

The SFR P/N 7062548 operates in a manner identical to the relay described in Manual H-886. The primary exception is the output contact configuration.

Two sets of form C contacts are supplied as outputs to the terminal of the relay. Reference to drawing 7265420 shows that the contacts are as listed below.

Terminal Arrangement

5		8	
	Normally open		Normally open
6		9	
	Normally closed		Normally closed
7		10	

## ADDENDUM

### OPERATION & MAINTENANCE MANUAL

H-886

Many users of E-MAX SFR Relays have asked for a lower internal analog delay. We have, therefore, lowered the analog delay from 6 cycles to 2 cycles (on a 60 Hz base). This was accomplished by lowering the value of R5 on the logic card from 27k ohms to 10k ohms. Any reference to 6 cycles of analog delay in this manual should be considered as 2 cycles of analog delay.

E-MAX recommends that the total minimum delay be not less than 6 cycles, i.e. 2 analog plus 4 digital.

### NOTICE

DC powered SFR's (125v and 48v) and replacement power supply circuit boards were being delivered with G.E. D42T8 transistors in positions Q302 and Q304. These transistors (E-MAX P/N 7009015), have been discontinued by the manufacturer. Therefore, until further notice, all new complete SFR's, replacement power supply boards (E-MAX P/N 7104900), and spare transistor orders will be supplied with Motorola MPS-A42 transistors (E-MAX P/N 6642817) in place of the D42T8. The replacement of these transistors (in pairs) will in no way alter the operation or performance of the SFR.

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## LIST OF DRAWINGS

<u>RELAY P/N</u>	<u>SCHEMATIC</u>
7062501	7265408
7062502	7265401
7062503	7265401
7062504	7265408
7062505	7265401
7062506	7265401
7062507	7265408
7062508	7265401
7062509	7265401
7062561	7265401
7062570	7265401

INTERNAL/EXTERNAL WIRING DIAGRAM: 7253401

OUTLINE DIAGRAM: 7098100

## 1. PURPOSE AND APPLICATION

The SFR-59 Underfrequency Relay is used in load shedding applications to trip at the critical underfrequency setting.

This relay finds application where trip frequency settings must be accurately maintained within  $\pm 0.01$  Hz and/or where very short trip delay intervals are required. Such accuracy is required to assure coordinated settings between relays of interconnected utilities. Unique inhibit features enable secure operations at very short trip delay settings. Secure operation is provided even in the presence of arcing noise, ac transfer, severe undervoltage conditions, loss of the power supply or loss of the signal input. Also, holding coils are provided to assure trip coil current until the associated circuit breaker operates.

There are three versions of the SFR-59 Underfrequency Relay, including 1A, 2A and 3A. The 1A version has one logic board, one target and one output relay, enabling one independent trip setting. The 2A version is identical to the 1A, except it has one additional logic board, target and output relay, enabling two independent trip settings. The 3A version is identical to the 1A, except it has two additional logic boards, target and output relays, enabling three independent trip settings.

All versions are available in three different input power configurations, including 48V dc, 125V dc and 117V ac, 60 Hz.

Refer to page i for a list of configurations/part numbers of SFR-59's covered in this manual.



## 2. OPERATING CHARACTERISTICS

The SFR-59 is designed to provide reliable repeatable indications of an underfrequency condition. The device has up to three electromechanical relay outputs which may be used to trip power circuit breakers.

Because of the special inhibit circuits, the relay will not trip due to loss of signal, loss of voltage or an internal power supply failure.

Special precautions have been taken to insure that the relay will not false trip due to noise. These precautions include careful control of the internal wiring and component placement as well as a test program which ensures that every relay will pass the noise specifications.

### 3. SPECIFICATIONS

Underfrequency Accuracy

$\pm .003$  Hz on 60 Hz base

Time Delay Accuracy

$\pm 1$  cycle

Surge Withstand Capability

The SWC test wave is an oscillatory wave, nominal frequency 1.5MHz.(1.0 to 1.5MHz range), 2.5kV (-0 +20%) crest value of the first half cycle peak, envelope decaying to 50% of the crest value of the first peak in 6 microseconds from the start of the wave. Source impedance of the surge generator used to produce the test wave to be 150 ohms. The test wave to be applied to a test specimen at a repetitive rate of not less than 50 tests per second for a period of at least 2.0 seconds.

The test wave is applied between all inputs and the case; between each input and all other inputs. This a differential and a common mode test. Each test is applied consecutively for two seconds. The relay must not falsely operate at four digital cycles delay.

Signal Loss Test

The relay will not falsely operate at four digital cycles delay when the power is removed, regardless of the rate.

Power Loss Test

The relay will not falsely operate at four digital cycles delay when the power is removed, regardless of rate.

Undervoltage Adjustment

40 to 70V rms (dc versions)  
60 to 70V rms (ac versions)

Target

2A Tap  
2A must operate, 200mA must release  
0.2A Tap  
0.2A must operate, 20mA must release

## Output Contacts

Refer to the following table.

PARAMETER	AMPÈRES AC OR DC AT 155V DC MAX.	
Holding Coil Tap	.2A	2A
Carry for 1 Second	10A	30A
Carry-Continuous	2A	6A
Resistance	1.3 $\Omega$	.20 $\Omega$
Impedance at 60Hz	1.45 $\Omega$	.20 $\Omega$
Break (Controlled by Release of Holding Coil)	0.2A	2A

Any other time-current characteristics may be found from  $k=i^2t$ .

TABLE 1  
OUTPUT CONTACT RATINGS

Underfrequency Range	49 to 59.98Hz
Frequency Setting Resolution	To .01Hz of desired setting.
Time Delay Resolution	1 cycle (after 32 ms int. analog delay)
Temperature	0° to 140°F
Humidity	0 to 95%
Isolation	Will withstand a one minute application of 1500V rms, 60 Hz, between each input and any other input or any input and case.
Features	Output contacts are sealed in.* Target indications are remembered even if power is lost. Flush mounting or panel mounting. Draw out case.

Outside Dimension

16-3/8" H x 6-11/16" W x  
10-1/2" D

Weight

25 lbs.

Burden

Less than 2VA

Time Delay

Front panel adjustment of 1  
to 64 cycles plus 2 cycles  
built-in to logic board.

Power Requirements

P/N's 7062501, 7062504,  
7062507 - 48Vdc nominal  
(34-57Vdc)

P/N's 7062502, 7062505,  
7062508 - 125Vdc nominal  
(90-152Vdc)

P/N's 7062503, 7062506,  
7062509 - 117Vac, 60Hz  
nominal (60-160Vac rms)

\*NOTE: The seal-in feature may be eliminated if desired by removing  
the following diodes from the Input Circuit Board:

CR214 on SFR-1A models.

CR214 and CR213 on SFR-2A models.

CR214, CR213, and CR209 on SFR-3A models.

#### 4. PERFORMANCE TESTING

The following test information applies equally to all SFR-59 models, with the exception of power supplied to the back panel, which differs from model to model. To check out an SFR-59, the test circuit of Figure 1 must be assembled. Also, an E-MAX Frequency Relay Calibrator, FRC-2A, or equivalent is required as a programmed signal source. The FRC-2A provides an accurate low frequency output of from 40 to 160V rms at 1A. The output frequencies are digitally set according to the desired period, namely Frequency 1 and Frequency 2. Frequency 2 may be programmed to occur at a delayed period of from 1 to 99 cycles. Particular performance tests are outlined in the following text with reference to the test circuit of Figure 1, and setting tables for the FRC-2A and the SFR-59.

##### A. Test Equipment Required

0-125V dc @ 1 Amp Power Supply (for dc units).

0-150V ac @ Amp Variac (for ac units).

E-MAX Frequency Relay Calibrator - FRC-2A.

Oscillator, HP 205AG or Equivalent.

Components shown in Figure 1.

Set Relay to trip at 59.9 Hz with 4 cycles of digital delay.

##### B. Underfrequency Accuracy

Assemble the circuit shown in Figure 1 and set the relay to the frequency shown on the accompanying table. The FRC-2A should be adjusted with Period No. 1 set to the untripped frequency as shown in the table. Period No. 2 should be set to the trip frequency. When a transfer is made between Period No. 1 and Period No. 2, the SFR-59 should trip and the target light for the appropriate frequency will be energized.

##### C. Timer Delay Accuracy

Assemble the circuit shown in Figure 1. Adjust the time delay switches on the FRC-2A to the time delay shown in the left-hand side of the accompanying table and adjust the relay to the proper value. Adjust Period No. 2 to the value shown under Period No. 2 on the table. Enable Period No. 1. Press the time delay enable switch. The FRC-2A should momentarily set to Period No. 2 and then transfer to Period No. 1. The SFR-59 should not trip. Adjust the time delay setting on the

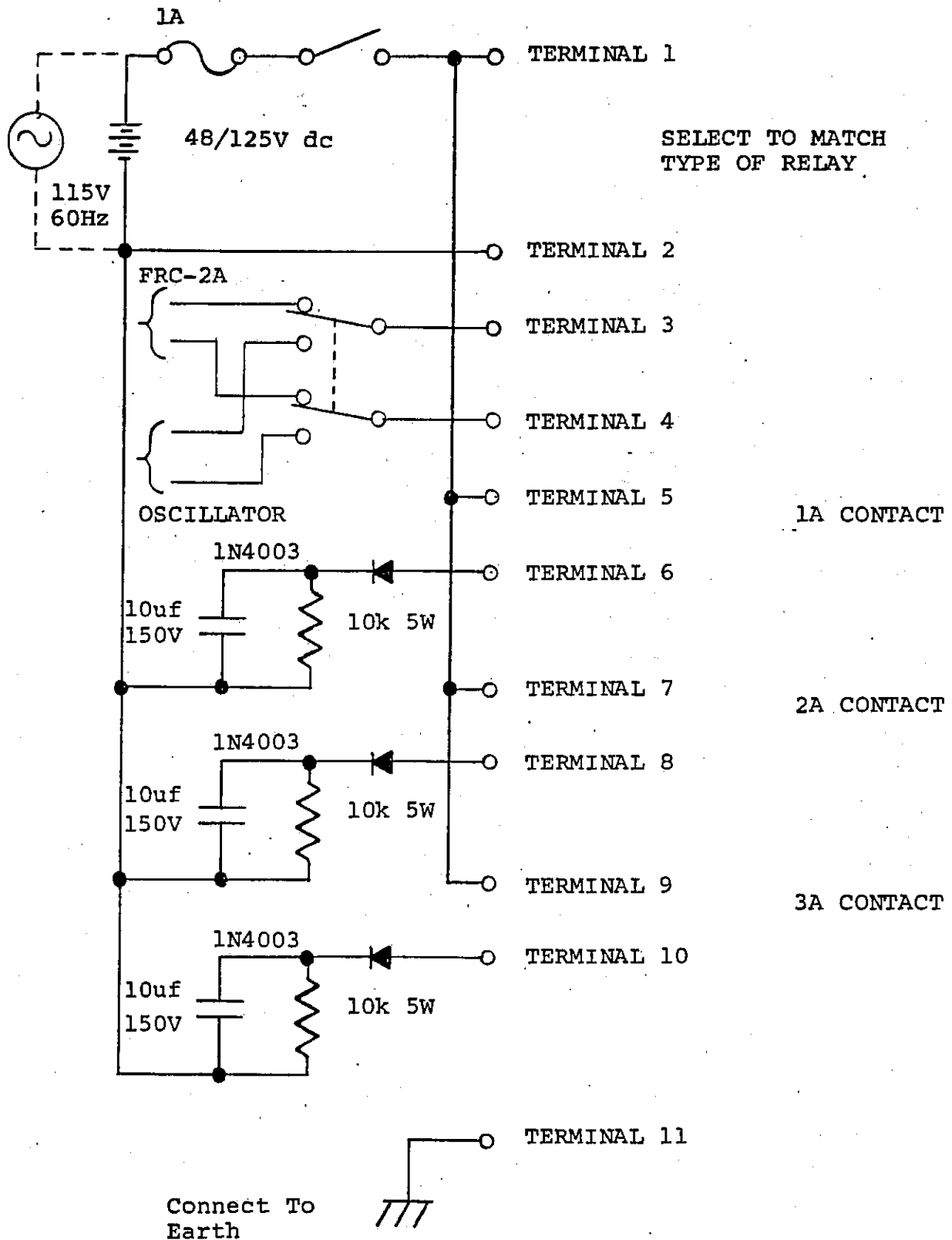


FIGURE 1 - TEST CIRCUIT

FRC-2A to the value shown in the right-hand column on the table. Again, press the delay enable switch. The SFR-59 should now trip. Repeat the procedure to each of the values in the table.

D. Underfrequency Out-of-Range Inhibit Tests

Assemble the circuit shown in Figure 1. Close oscillator switch, and turn the oscillator amplitude up until the ready light turns on. Adjust the oscillator frequency from 60Hz to 20Hz. The SFR-59 should trip and remain tripped all of the time that the oscillator frequency is below the trip point. Then, as the oscillator is adjusted from this value to 60 Hz, the SFR-59 will reset as the trip frequency is approached and remain reset for all values over the trip frequency.

### UNDERFREQUENCY ACCURACY

UNTRIPPED	TRIPPED*	RELAY SETTING
55.92	55.88	55.9
56.02	55.98	56.0
56.12	56.08	56.1
59.02	58.98	59.0

\*Add 10 $\mu$ s for solid trip.

### TIME DELAY ACCURACY

TIME 1	PERIOD 1	PERIOD 2	RELAY SETTING FREQUENCY	TIME 2*	RELAY SETTING
3	60.0	59.8	59.9	5	2
5	60.0	59.8	59.9	7	4
9	60.0	59.8	59.9	11	8
17	60.0	59.8	59.9	19	16
33	60.0	59.8	59.9	35	32

\*Time may vary  $\pm 1$  cycle according to internal delay but will be consistent for each logic board over the entire range.



## 5. INSTALLATION

### A. Receiving Inspection

The SFR-59 is carefully tested and inspected at the factory prior to shipment. Before unpacking, inspect the shipment container for visible damage; after unpacking, inspect the equipment for any possible damage incurred during transit. If the unit is damaged, immediately file a claim giving a full damage report to the carrier, and notify the nearest E-MAX area representative.

### B. Mechanical

The SFR-59 may be either panel mounted or stud mounted. The required hole patterns and cutouts are shown in drawing number 7098100.

### C. Electrical

After the relay is mounted, refer to the Wiring Diagram 7253401, for wiring connections. Connect Terminal 11 to earth.

## 6. OPERATING INSTRUCTIONS

Refer to Figure 2 for the location of the controls.

### A. Frequency Setting

#### CAUTION

DO NOT CHANGE FREQUENCY OR TIME DELAY  
SETTING WHILE THE RELAY IS IN THE OUTER  
CASE.

To set either the trip or close frequencies, locate the appropriate switches on the SFR-59. Then refer to Table 2 and locate the code for the particular frequency to be used. Start with the top switch, set it to either 1 or 0 as determined by the left digit in the table. Continue to set the switches by moving down the panel and across the table.

A 1 or 0 is set by removing the screw and inserting in the appropriate location.

Table 2, Underfrequency Versus Binary Code Settings, is obtained from:

$$F_s = \frac{1}{5F \times 10^{-4}} - 3072$$

where  $F_s$  is the frequency setting, and  $F$  is frequency in cycles per second.

The frequency setting,  $F_s$ , is then converted to a binary code. Although Table 2 lists frequency settings for every tenth cycle, the frequency can be set to a resolution of 0.02Hz.

### B. Time Delay Setting

#### CAUTION

DO NOT CHANGE FREQUENCY OR TIME DELAY  
SETTING WHILE THE RELAY IS IN THE  
OUTER CASE.

The time delay is set in a manner similar to the frequency with a binary code. The numbers are found on the right of the delay screw adjustments. To adjust the delay, set the screws to the "0" or "1" position that corresponds to the binary cycle delay. Then, the cycles of delay will be the sum of the binary digits, plus two cycles. Add all of the numbers to obtain the total time delay.

As an example, suppose the desired delay is 11 cycles. The bottom switch would be set to 1, the second and third switches would be 0, the fourth switch would be a 1 and the rest would be 0, thus:

$$11 \text{ cy} = 9 \text{ cy} + 2 \text{ cy (at 60 Hz)}$$

C. Undervoltage Adjustment

The undervoltage threshold may be adjusted using the potentiometer on the far right. The level is decreased by turning in a clockwise direction.

D. Current Tap Setting

To set the current sense tap to the 0.2A setting, place the programming wire in the screw terminal located in the lower right-hand part of the current sense relay. When a 2A setting is desired, put the wire in the lower middle screw terminal.

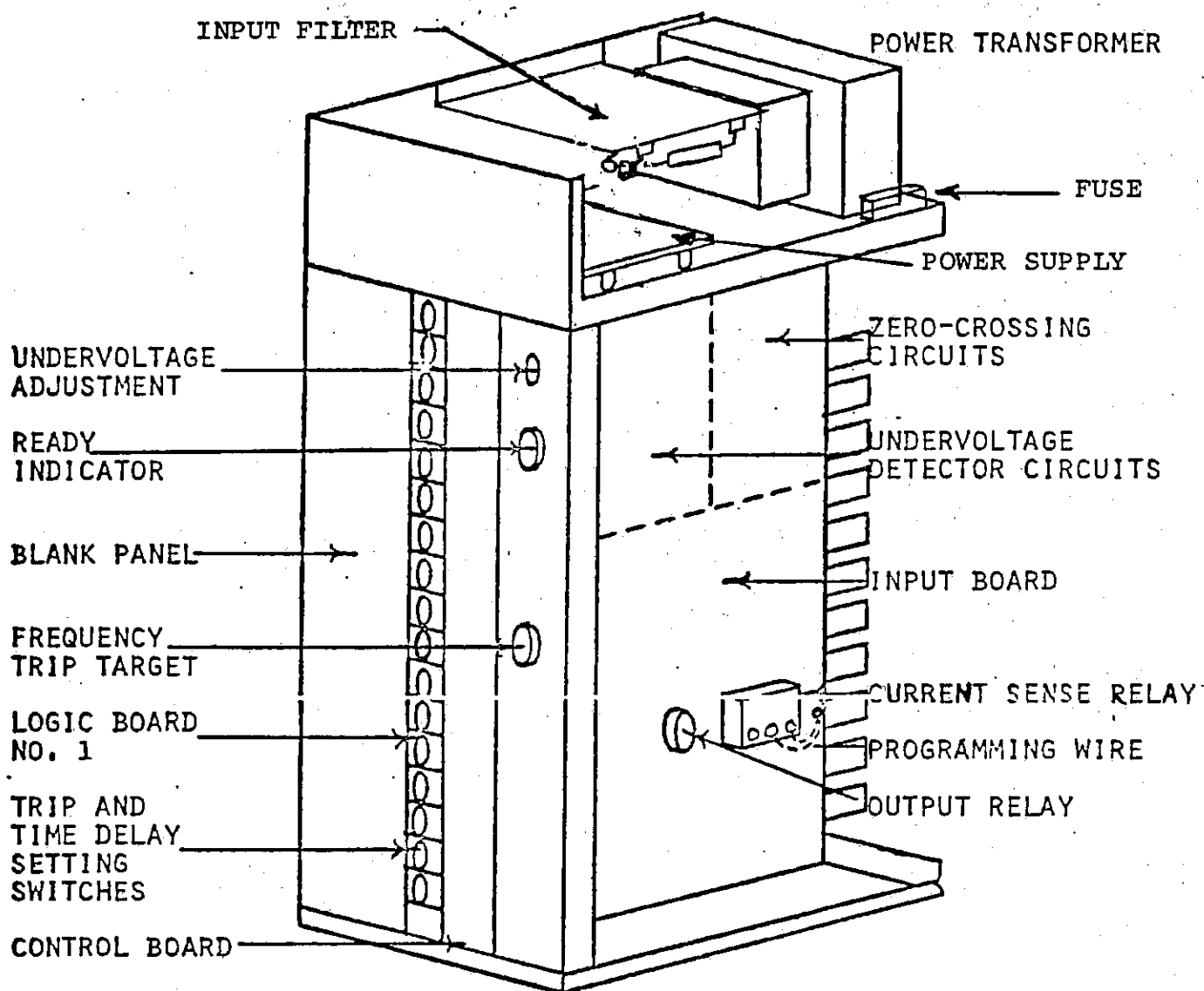


FIGURE 2A  
SFR-59-1A UNDERFREQUENCY RELAY

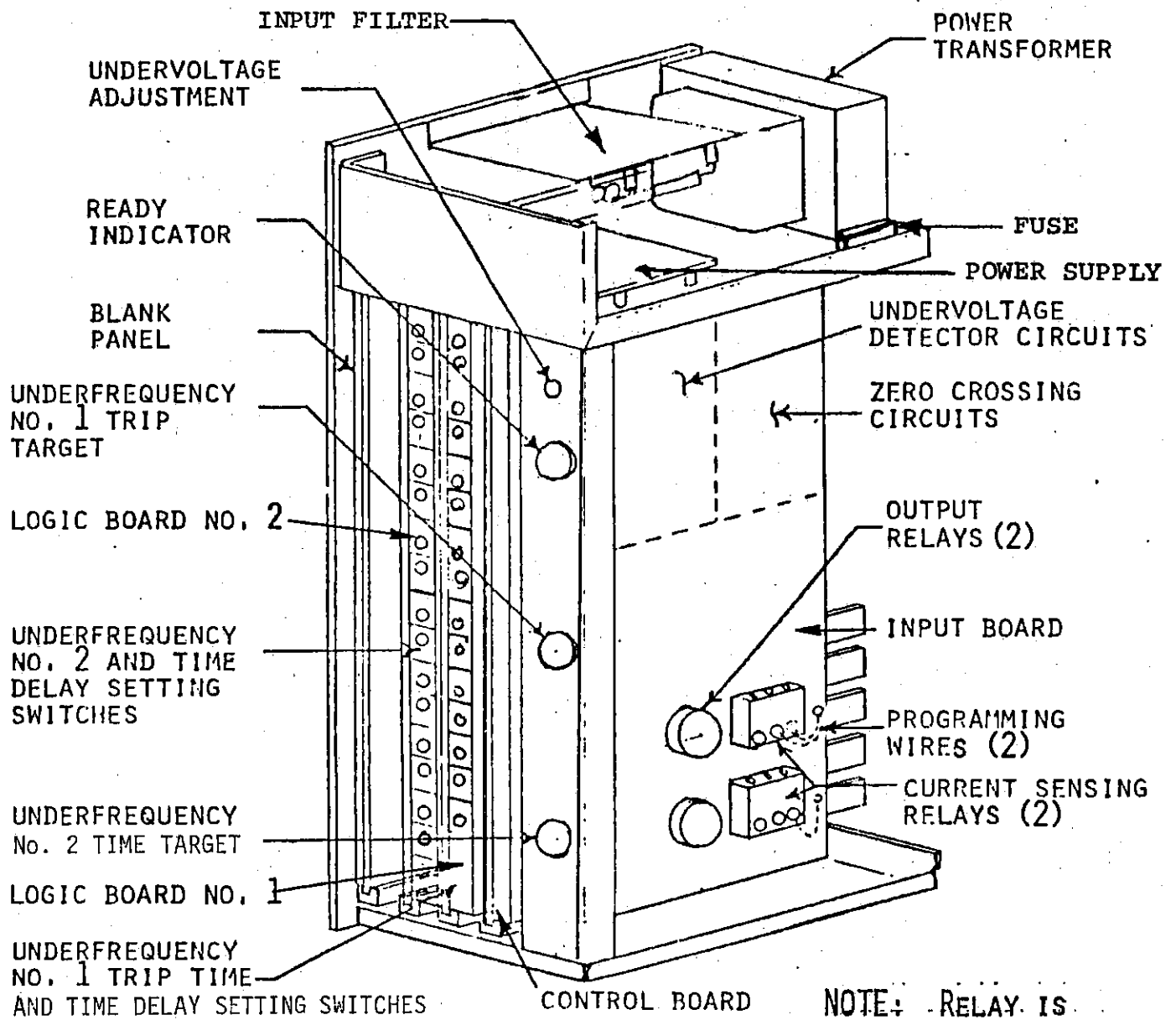
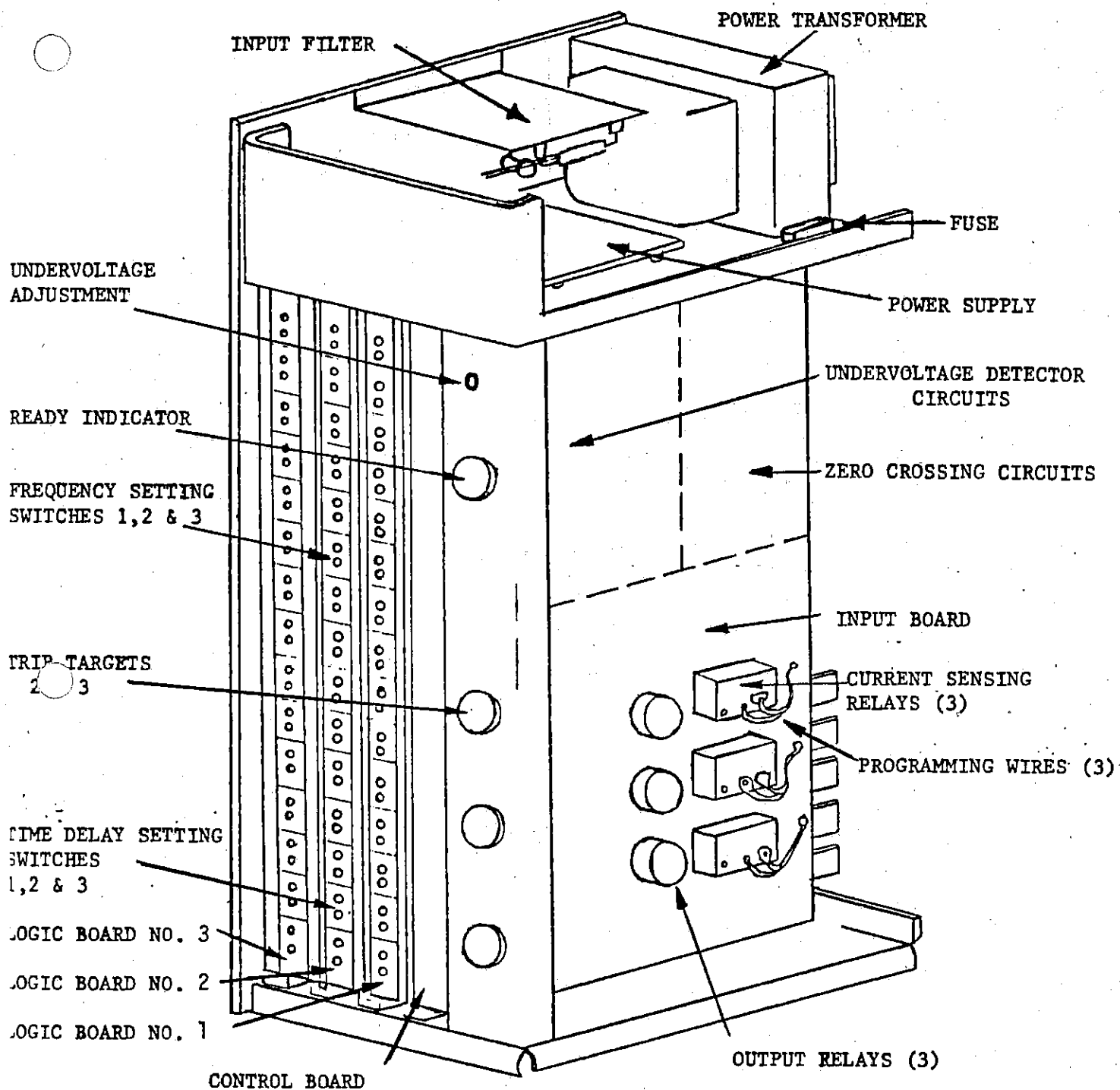


FIGURE 2B

SFR-59-2A UNDERFREQUENCY RELAY



NOTE: RELAY IS SHOWN  
REMOVED FROM CASE.

FIGURE 2C

SFR-59-3A UNDERFREQUENCY RELAY

TABLE 2  
UNDERFREQUENCY  
VERSUS  
BINARY CODE SETTINGS  
CODE

FREQUENCY										
52.	1	1	0	0	0	0	0	1	1	0
52.1	1	0	1	1	1	1	1	1	1	1
52.2	1	0	1	1	1	1	0	1	1	1
52.3	1	0	1	1	1	1	0	0	0	0
52.4	1	0	1	1	1	0	1	0	0	1
52.5	1	0	1	1	1	0	0	0	0	1
52.6	1	0	1	1	0	1	1	0	1	0
52.7	1	0	1	1	0	1	0	0	1	1
52.8	1	0	1	1	0	0	1	1	0	0
52.9	1	0	1	1	0	0	0	1	0	1
53.	1	0	1	0	1	1	1	1	0	1
53.1	1	0	1	0	1	1	0	1	1	0
53.2	1	0	1	0	1	0	1	1	1	1
53.3	1	0	1	0	1	0	1	0	0	0
53.4	1	0	1	0	1	0	0	0	0	1
53.5	1	0	1	0	0	1	1	0	1	0
53.6	1	0	1	0	0	1	0	0	1	1
53.7	1	0	1	0	0	0	1	1	0	0
53.8	1	0	1	0	0	0	0	1	0	1
53.9	1	0	0	1	1	1	1	1	1	1

54.	1	0	0	1	1	1	0	1	1	1
54.1	1	0	0	1	1	1	0	0	0	1
54.2	1	0	0	1	1	0	1	0	1	0
54.3	1	0	0	1	1	0	0	0	1	1
54.4	1	0	0	1	0	1	1	1	0	0
54.5	1	0	0	1	0	1	0	1	0	1
54.6	1	0	0	1	0	0	1	1	1	1
54.7	1	0	0	1	0	0	1	0	0	0
54.8	1	0	0	1	0	0	0	0	0	1
54.9	1	0	0	0	1	1	1	0	1	1
55.	1	0	0	0	1	1	0	1	0	0
55.1	1	0	0	0	1	0	1	1	0	1
55.2	1	0	0	0	1	0	0	1	1	1
55.3	1	0	0	0	1	0	0	0	0	1
55.4	1	0	0	0	0	1	1	0	1	0
55.5	1	0	0	0	0	1	0	0	1	1
55.6	1	0	0	0	0	0	1	1	0	1
55.7	1	0	0	0	0	0	0	1	1	1
55.8	1	0	0	0	0	0	0	0	0	0
55.9	0	1	1	1	1	1	1	0	0	1
56.	0	1	1	1	1	1	0	0	1	1
56.1	0	1	1	1	1	0	1	1	0	1
56.2	0	1	1	1	1	0	0	1	1	1
56.3	0	1	1	1	1	0	0	0	0	0



56.4	0	1	1	1	0	1	1	0	1	0
56.5	0	1	1	1	0	1	0	0	1	1
56.6	0	1	1	1	0	0	1	1	0	1
56.7	0	1	1	1	0	0	0	1	1	1
56.8	0	1	1	1	0	0	0	0	0	1
56.9	0	1	1	0	1	1	1	0	1	1
57.	0	1	1	0	1	1	0	1	0	1
57.1	0	1	1	0	1	0	1	1	1	1
57.2	0	1	1	0	1	0	1	0	0	1
57.3	0	1	1	0	1	0	0	0	1	0
57.4	0	1	1	0	0	1	1	1	0	0
57.5	0	1	1	0	0	1	0	1	1	0
57.6	0	1	1	0	0	1	0	0	0	0
57.7	0	1	1	0	0	0	1	0	1	0
57.8	0	1	1	0	0	0	0	1	0	0
57.9	0	1	0	1	1	1	1	1	1	0
58.	0	1	0	1	1	1	1	0	0	0
58.1	0	1	0	1	1	1	0	0	1	0
58.2	0	1	0	1	1	0	1	1	0	0
58.3	0	1	0	1	1	0	0	1	1	1
58.4	0	1	0	1	1	0	0	0	0	1
58.5	0	1	0	1	0	1	1	0	1	1
58.6	0	1	0	1	0	1	0	1	0	1
58.7	0	1	0	1	0	0	1	1	1	1

58.8	0	1	0	1	0	0	1	0	0	1
58.9	0	1	0	1	0	0	0	0	1	1
59.	0	1	0	0	1	1	1	1	0	1
59.1	0	1	0	0	1	1	1	0	0	0
59.2	0	1	0	0	1	1	0	0	1	0
59.3	0	1	0	0	1	0	1	1	0	1
59.4	0	1	0	0	1	0	0	1	1	1
59.5	0	1	0	0	1	0	0	0	0	1
59.6	0	1	0	0	0	1	1	0	1	1
59.7	0	1	0	0	0	1	0	1	1	0
59.8	0	1	0	0	0	1	0	0	0	0
59.9	0	1	0	0	0	0	1	0	1	1

## 7. CALIBRATION AND ADJUSTMENT

Due to the construction of the SFR-59, no calibration is necessary after the initial adjustment of the relay. However, a periodic 6 month check is desirable to determine if the relay is still operating properly. To perform this test, refer to the section on Performance Testing. No adjustments are required on the SFR-59 other than the front panel adjustments as listed in the Operating Instructions. These consist of the undervoltage adjustment, the frequency adjustments, and the time delay settings.

## 8. MAINTENANCE

Due to the construction of the SFR-59, very little maintenance should be required. However, a periodic 6 month check for proper operation of the relay is recommended. This check should be performed as listed in the Calibration and Adjustment section of this manual. At the time of this check, it would be desirable to inspect the contacts of the output relay for degradation, and to clean the contacts if necessary. Should trouble be encountered in the routine test, refer to the section on Trouble Isolation.

## 9. PRINCIPLES OF OPERATION

In this discussion the terms "U" and "IC" are used interchangeably.

### A. Basic Relay

The signal is first applied to the SFR-59 through pins 3 and 4 of the input board. The signal is then routed to an undervoltage detector which is shown on the detailed schematic. The function of this device is to disarm the relay whenever the signal voltage is below a sufficient amount to enable the relay to operate properly. The signal is also applied to a zero crossing detector which is shown on the detailed schematic. The purpose of the zero crossing detector is to provide an output pulse on every positive going zero crossing of the input signal. These positive pulses are applied to the logic boards as a reset signal. It is applied through the reset generator which conditions the pulse to a form that is acceptable to the logic.

A 200kHz clock is located on the control board. Also, the clock signal is applied to the logic board. The clock pulses are then counted in a base counter and then the count in the base counter is compared in the gating to a preset count which is set in the switches located on the front of the logic boards. When the count in the counter exceeds the preset amount set in the switches, an output pulse is supplied at the output of the gating. Thus, if the reset signal is applied to the base counter before the counter counts to the preset amount, the input frequency must be higher than the preset frequency. An underfrequency pulse will not occur at the end of the gating. However, if the counter is allowed to count to the comparison point before the reset occurs, the underfrequency pulse will be generated at the output of the gating once a cycle. This pulse is then applied to the time delay counter which acts in a manner similar to the base counter to count the number of underfrequency cycles. Switches are coded to preset the desired number of underfrequency cycles that are necessary to cause the relay to trip. When coincidence occurs between the time delay counter and the preset time delay switches, an output pulse is generated at the output of the time delay gating which then sets the output flip-flop and causes the trip control relay to be energized. When the underfrequency condition disappears, a reset counter is used to reset the output flip-flop and de-energize the trip control relay.

When the trip control relay is energized, a ground is applied through pin 2, through the contacts to pin 1 of the logic board and to pins 23 on a 1A, 23 & 25 on a 2A and 23, 25 & 27 on a 3A, on the input board. This ground is used to energize the trip output relay K203. However, if the input signal is lower than the necessary amount to cause the relay to operate properly, the undervoltage contacts located on the input board will not be closed, and a ground will not be applied at pin 2 of the logic board number 1. Thus, the output trip relay cannot trip.

When the output relay K203 is energized, contacts located near pins 5 and 6 are closed. When these output contacts close, current flows from the external circuitry through input board trip relay K202 and out to pin 6 of the input board. When the current exceeds either 0.2A or 2A, as programmed by the current sense strap, the contact will close on the current sense relay, K202. This contact will then seal in the trip output relay, K203, through diode CR214. At the same time, it will cause the underfrequency target memory relay, K204, to be latched. This relay is a magnetic latching relay which will remember its latch condition until the reset switch, S501, is pressed. When this happens, the current will flow through the delatch coil of relay K204. When K204 closes, power will be applied to lamp DS201.

Power is applied to the SFR-59 through the power supply and is regulated through Q501, resistors R502, R503, R501, and R504. Each of the logic and control boards has an individual regulator to further regulate the voltage.

## B. Detailed Schematic

### 1. Zero Crossing Detector

The function of the zero crossing detector is to compare the input signal to zero. When the input signal exceeds zero by a small amount, an output is produced. This circuit operates in the following manner: The input signal is applied through pins 3 and 4, through resistors R204 and R205 to the signal clipping diodes, CR204 and CR203. Then, the signal is applied to the zero crossing detector which consists of transistors Q201 and Q204. The output is supplied through transistors Q202 and Q205, which function as an amplifier for transformer T202. The output of transformer T202 is then applied through pins 14 and 15 on the input board to the control board through pins 2 and 3.

## 2. Reset Generator

The reset generator is located on the control board and has the functions of limiting and shaping the signal to a constant width and amplitude for use as a pulse to reset the base counter. The input signal from the zero crossing detector is first clipped, using diodes CR101 and CR102, to a value which is safe for use with the integrated circuits. Next, the signal is passed through a single-shot which consists of IC101; where the signal is formed into a constant pulse width and constant amplitude reset signal. This signal, known as the base counter reset, is then applied to the logic cards through pin 5 of the control board.

## 3. Clock

The clock oscillator is a 200kHz oscillator which provides the basic timing for the logic boards. It is located on the control board, and consists of transistors Q101, Q102 and crystal Y101. Q103 and its associated circuitry functions as an output amplifier for the oscillator. The signal is passed through IC101 and IC102 to pin 6 of the control board, where it is transmitted to the logic board.

## 4. Undervoltage Detector

The function of the undervoltage detector is to prevent the SFR-59 from tripping in the presence of undervoltage. The input signal is applied to the undervoltage detector from transformer T201. The signal is then rectified by rectifier CR205 and attenuated by the voltage divider consisting of R212, R213, and R214. CR206 clips any unusual voltage surges. The signal then is applied to Q206 which is an emitter follower. The rectified signal is then filtered by R216 and C204, and is applied through another amplifier, Q207, to a Schmidt trigger consisting of Q208 and Q209. When the input signal is of a sufficient magnitude to switch the Schmidt trigger, the voltage between R218 and Q208 will switch from 12V to approximately 6V. This will turn on transistor Q210 which is a driver amplifier for the undervoltage relay, K201. If transistors Q211 and Q212 are saturated to ground, then the undervoltage relay, K201, will be energized. In order to saturate transistors Q211 and Q212 to ground, the power voltage must be above 11V. If this is the case, current is passed through R225 to capacitor C205. When capacitor C205 charges to approximately 1V, transistors Q211 and Q212 will be energized. The charging time constant is approximately 200 to 500 milliseconds. If the power supply level should

drop below 10V, the voltage change will discharge capacitor C205 through diode CR207. This will discharge capacitor C205 within 1 millisecond. Thus, when the relay is initially turned on, approximately 500 milliseconds is required before the SFR-59 is on. This time delay enables the logic to be in its correct operating condition. However, if the relay is turned off, it will discharge within 1 millisecond and disarm the relay.

If the input signal drops below the required level as determined by the undervoltage adjustment, potentiometer R213, capacitor C205 will also be discharged. This is accomplished by the Schmidt trigger when it recognizes an undervoltage condition through R231 to transistor Q215, which causes it to saturate to the +12V bus. This causes current to flow down through R232 into transistor Q216 which discharges time delay capacitor C205. The ready lamp, DS204, is energized whenever the undervoltage relay is in a proper condition to cause the relay to trip. Also, the undervoltage relay contacts are routed through input board pin 20 to all the logic boards where they are connected in series with the output relay, thus preventing tripping in the event of undervoltage or low power supply conditions.

### C. BASIC LOGIC OPERATION

Having followed the generation of the clock signal and the base counter reset signal, one may now understand the basic operation of the underfrequency relay.

Referring to the schematic, one finds the base counter, which is the main frequency sensing circuitry in the relay. In a particular relay, there may be as many as three base counters. The clock input is applied through logic board pin C<sub>1</sub> to IC15 where it is gated and applied to the first flip-flop of the base counter, IC1. IC1 through IC6 forms a simple binary counter which counts the number of clock pulses between the base counter reset pulses. The base counter reset pulses are then applied through the logic board pin BCR to IC12 which inverts the signal. The base counter reset is then used to reset the base counter to zero. Thus, just before being reset, the count in the base counter is an indication of the frequency of the input signal. The count in the counter is then applied to comparison gates IC13 and IC16. From these two integrated circuits the signal is applied to two gates located in IC11 and finally to IC16 for the final comparison. The function of these comparison gates is to compare the count in the counter with a preset code in switches S1 through S10. In the event that a comparison is generated, the input frequency must be lower than the present frequency in switches S1 through S10. Thus, the pulse that would occur at Gate IC16, pin 8, is an indication of an underfrequency condition for one



cycle. This signal is then applied through the underfrequency programming jumpers to IC15 and from there to a time delay counter consisting of IC7 through IC9. The time delay counter then counts the number of underfrequency cycles, and a comparison is made between the count in the counters and the time setting in switches S11 through S16. The comparison is made in the integrated circuit IC14. The output of IC14, pin 8 is a pulse whenever an underfrequency condition has persisted longer than the preset time delay. This output pulse then sets the underfrequency flip-flop, IC11, to a state which will cause the relay driver, Q1, to energize the output relay, K1. This relay is then used to trip the SFR-59. R5 and C7 determine the analog delay of the logic board. Q3 is normally saturated to ground. When a fault occurs, Q3 turns off, allowing C7 to charge to approximately 1V dc, causing Q1 to energize relay K1.

A reset counter consisting of IC10 is provided to reset the time delay counter when the underfrequency condition returns to normal. The reset counter counts the number of base counter reset pulses which are applied to the logic of the input card. However, if an underfrequency condition exists, a pulse will occur once a cycle out of the mode programming jumper and reset the reset counter. Thus, the reset counter will oscillate between a count of zero and a count of one all of the time an underfrequency condition persists. When the underfrequency condition clears, there will no longer be underfrequency pulses occurring at the reset input of the reset counter and this counter will then be allowed to count to its maximum of three counts. When this maximum is reached, IC12 will sense the full state of the counter and will reset the time delay counter. It will also reset the underfrequency flip-flop and allow K1 to become de-energized.

#### D. OUTPUT CIRCUITS

The final output circuits for the SFR-59 are located on the right side of the schematic. Considering output circuit number 1, located near the top of the page, pins 5 and 6 are output contacts. Relay K1 is energized by the trip condition, closing the output contacts and causing current to flow from pin 5 through the output contacts to the current sensing relay and out pin 6. When the output current exceeds either 0.2A or 2A, depending on the output current sense programming, the contacts of the output current sense relay will be energized. This will provide a ground to the cathode of diode (CR209, CR213, CR214) which will seal the output relay. At the same time, memory relay K204 will be energized. This is a magnetic latching relay which will remember its last condition until the reset switch, S501, is pressed. When the memory relay, K204, is latched, a contact on this relay will close and apply a ground to the target number 1 light, DS201, to turn on

the light which indicates the target condition. The light will then remain lit until reset by switch, S501.

E. DC SUPPLY (125Vdc or 48Vdc - See appropriate Schematic)

The input power is supplied to pins 1 and 2 through a filter consisting of L501 and L502 and capacitors C502 and C503. A varistor is provided to clip off any transients which may be on the battery line. Also, diode CR302 is used in the event that the relay should be connected in the reverse direction. The dc is then applied through dropping resistor R505 to zener diode CR314 which acts as a voltage source for a multivibrator used to drive the inverter transistors. The multivibrator consists of Q306 and Q305 and the associated circuitry necessary to make a free running multivibrator. As soon as the dc signal is applied to the relay, the multivibrator begins to oscillate and switches the dc signal through switching transistors Q302 and Q303. Thus, the input voltage is switched into a square wave of approximately a 330 cycle oscillation. The oscillating voltage is then applied to two main power supplies. Pins 16 and 17 are connected to an isolated supply consisting of rectifier CR201, filter capacitors C206 and C201, and filter resistor R201. The zener diode, CR202, is used to clip any unusual transients which may be passed through the filter. C208 and C207, along with R202 and R203, provide for a balanced supply consisting of a minus voltage with a common point between the two resistors. This voltage is used to power the zero crossing detector. The square wave is also applied through pins 9, 11, and 13 (125V dc version) or pins 7, 11 and 15 (48V dc version), to rectifier diodes CR311 and CR312. Filter capacitor C307 is used to smooth the rectified square wave and regulator transistor Q201 provides approximately 12V dc to supply the rest of the circuitry even though the input voltage may vary. This 12V dc is fed directly to the input board for use in energizing the trip relays. Also, the logic boards and the control board are supplied with power through resistors (R501, R502, R503 and R504) to individual regulators located on logic boards. Considering a typical regulator located on logic board number 1, the power is dropped by the 200 milliamp drain of the logic card to approximately 8V at the input pin of logic board number 1, pin 12.

Regulator Q2 then provides a constant 5V to power the logic on the logic board.

## F. AC Supply

The entire power supply system, consisting of the individual regulators, and the main regulator Q501, is identical in the ac supply to the analogous components in the dc supply. The power is again applied through pins 1 and 2 and filter L501 and L502, C503 and C502 to the transformer T501. The circuitry following the transformer is basically a tap changer which automatically adjusts itself to the input signal. This provides a roughly filtered signal across capacitor C402. Transistor Q501 is used to regulate this slightly varying voltage to approximately 12V dc as was done in the case of the dc supply. Transistor Q404, resistor R417, and diode CR401 are identical to the corresponding diode and resistors Q307, CR313 and R315 in the dc supply. The ac voltage on pins 6 and 7 is applied through rectifiers CR416 and CR417 which function as a full-wave rectifier to capacitor C401. Thus, a dc voltage is provided which is proportional to the rms value of the ac input. Transistors Q401, Q402, Q403 function as switching transistors to turn the various SCR's off as the input voltage increases.

Initially, a low turns ratio is required. SCR401 and SCR406 will be energized as the signal is increased above 40 volts. The switching is accomplished in the following manner: A constant voltage is applied to the cathode of CR420 which acts as a reference voltage. As the power supply voltage increases across each of the voltage-divider resistors consisting of R401, R402, R404, R405, R407, and R408, a point will eventually be reached across R407 and R408 where Q403 will be saturated. This will cause current to flow through diodes CR402 and CR414 which will back-bias SCR401 and SCR406, thus turning them off.

The next diodes in the chain, SCR402 and SCR405, will not be energized every cycle. As the voltage continues to increase, a level will be reached where R404 and R405 cause transistor Q402 to become saturated, which turns on diodes CR405 and CR412. As the voltage continues to rise, a similar process causes Q401 to turn off SCR403 and SCR404. Thus at the highest voltages, only the rectifying diodes CR408 and CR409 are being used to supply power to filter capacitor C402. It should be noted that only the SCR connected to the highest tap ratio in the chain which is not being turned off by an appropriate transistor is actually allowed to conduct. As an example, consider SCR401 and SCR402. If SCR401 was energized as the sine wave approached its crest (as soon as SCR401 fired), SCR401 would back-bias SCR402. However, if SCR401 was never allowed to energize, because it was turned off by its diode

SCR402, then SCR402 could conduct, and it would back-bias SCR403.

## 10. TROUBLE ISOLATION

To locate any defective section of the SFR-59, refer to the schematic. Using the wave forms and voltages shown at each of the pin numbers, selectively test each pin until a wave form or voltage is discovered which does not agree with the schematic. This procedure should enable the technician to discover the faulty section of the relay.

### A. Clock

If the clock oscillator is not oscillating, as determined by locating the appropriate wave form on pin 6 of the control board, then check pin 1 on IC102. The wave form at this point should be very similar to the output. Proceed toward Q101 and test for the appropriate wave form. If the oscillation is not present at the emitter of Q101, test transistor Q101 with an ohmmeter. If the transistor tests correctly, check for the proper voltage on the collector of Q101. If these conditions are present, crystal Y101 must be defective.

### B. Zero Crossing Detector

To locate a problem in the zero crossing detector, first connect an oscilloscope across CR204 and CR203. A half-volt square wave should appear at this point. Next test the output, pins 3 and 4, of T202. This should be approximately a 20V pulse as shown in the wave form for pins 14 and 15. If this wave form is not present, one of the transistors, Q201, Q202, Q203, or Q205, must be defective. Respectively, test the emitter of Q205 and the junction of R211 and R209 for the +12V and -12V. The tests should be made with respect to the junction of R202 and R203. In these tests, the ready light should be operating properly. If the ready light is not on, Q213 will be applying a short circuit from pins 3 and 4 of T202. Therefore, no output will be obtained.

### C. Reset Generator

To test the operation of the reset generator, the proper input should appear at pins 2 and 3. If this is not the case, the problem is in the input board. If the output of pin 5 on the control board is not correct, check to see that the input pulse is clipped between 5V and 0V at the input of IC101, pin 5. If this wave form is not present, diodes CR101 and CR102 are probably defective. If the wave form is present, IC101 is probably defective.

#### D. Undervoltage Detector

To locate problems in the undervoltage detector, first test the input to the base of Q206. If the wave form is not as shown, check the voltage levels on the Schmidt trigger, consisting of Q208 and Q209. These voltages are shown for an input voltage of the proper level to turn the light on. If the input voltage is above 6V at the base of Q207, the Schmidt trigger should be in its turned-on condition, and the voltages should be as shown surrounding Q208 and Q209. If the Schmidt trigger is not defective, check the collector of Q210 for the proper voltage. If the proper voltage is found, check the collector of Q211. At this point, the collector should be saturated to ground. If this is not the case, measure the voltage across CR208 which should be 10V. If this is not the case, measure the voltages at Q215, Q216, and Q212. This should enable the defective component to be found. If the voltage at the collector of Q211 is correct, K201 is defective.

#### E. Logic Tests

Each flip-flop, pins 5 or 9, should produce a square wave of progressively lower frequency. That is, the output of IC1, pin 5, will be half the clock frequency; the output of IC1, pin 9, will be one-fourth the clock frequency, and so on until the output of IC6, pin 9, is tested. However, the outputs of the last flip-flops will not necessarily be symmetrical. The output of these flip-flops can be most conveniently found on the front panel switches. Once all the flip-flops have been determined to be operating correctly, code the input frequency to a trip frequency. Pulses should then appear on the output of IC16, pin 6 and on pins 3 and 6 of IC11. If this is the case, pulses should appear on IC16, pin 8, and they should disappear whenever the input frequency is greater than the trip frequency. If the pulses appear, the relay is operating properly on underfrequency. These pulses should then be applied to the input of the time delay counter, IC7, pin 3. If this is the case, proceed to check the time delay counter in a manner similar to the base counter. Also, check IC14 to see that pulses appear when the frequency is underfrequency. If they do, the trouble with the relay is probably in the underfrequency flip-flop or the output driver. If they do not, the reset counter must be tested.

To test the reset counter for proper operation, code the frequency to a non-trip frequency and check to see that the base counter reset pulses appear on pin 3 of IC10. Also, no pulses should appear on pins 1 and 13, of IC10. The counter

should continue to count in a manner similar to the base counter. For every fourth base counter pulse in, an output pulse should be obtained on pin 8 of IC12, and should be applied to the input of each of the flip-flops of the time delay counter. When the input frequency is below the trip frequency, pulses should appear on pins 1 and 13 of IC10, and no output should appear on pin 8 of IC12. If this happens, the reset counter is operating properly.

If the relay fails to pass the underfrequency inhibit test, check the output of IC17. A logic level should appear at the output of IC17, pin 8, for a period of time between approximately 25 milliseconds and the next base counter reset. When this occurs, the output of IC18, pin 8, should go low for this period of time. Also, at IC15, pin 3, the clock pulses should disappear during this period of time. If this is not the case, then either IC17, IC18, or IC15 is defective.

#### F. Output Circuit

To determine if the various output and memory relays are operating properly, measure the appropriate wave form and refer to the Principles of Operation for the various sequences. This should locate the defective component.

#### G. DC Supply

To check the dc power supply, first determine if the inverter is running as shown by the wave form, pin 1, of T501. If the inverter is not running, measure the various voltages as shown on the schematic which should enable the defective component to be located. If the inverter is oscillating, check the wave forms between pins 16 and 17 for power value. If these prove to be correct, check the voltage across R202 and R203. This should locate the defective components in the isolated supply. If the +12V or +5V supplies in the unit are defective, measure the wave form on CR313 and C309. If these wave forms are correct, continue to measure the various wave forms or the various voltages at the emitter of Q501 and to each of the inputs of the logic boards. If these voltages all prove to be correct, measure the 5V supply on each of the logic boards and the control board.

#### H. A. C. Supply

To determine if the ac power supply is operating properly, first apply 115 V ac and measure the output of Q501 on the emitter. If this value is approximately 12V, proceed to determine the trouble as listed under the dc-supply trouble shooting procedure for the input to the various logic and control boards. If these values are correct, apply an input voltage of zero and slowly increase to 140 V. The value of the

voltage across capacitor C402 should change values as shown on the Tap Value Table, Table III. If one of the tap changes does not occur, the trouble should be in the circuitry associated with the switching transistor listed in the table. Knowing the voltage at which the tap change failed, and measuring the appropriate wave forms and voltages as shown on the schematic should enable the defective component to be located.

Tap	Input Voltage
1st	75
2nd	100
3rd	115

TABLE III

TAP VALUES

## 11. ORDERING INFORMATION

When ordering parts, send the model number and name of the equipment; and the reference designator, part number, description, and quantity desired of the component (s) to:

E-MAX Instruments, Inc.  
Sales Department  
14 Inverness Drive East (A-124)  
Englewood, CO 80112



