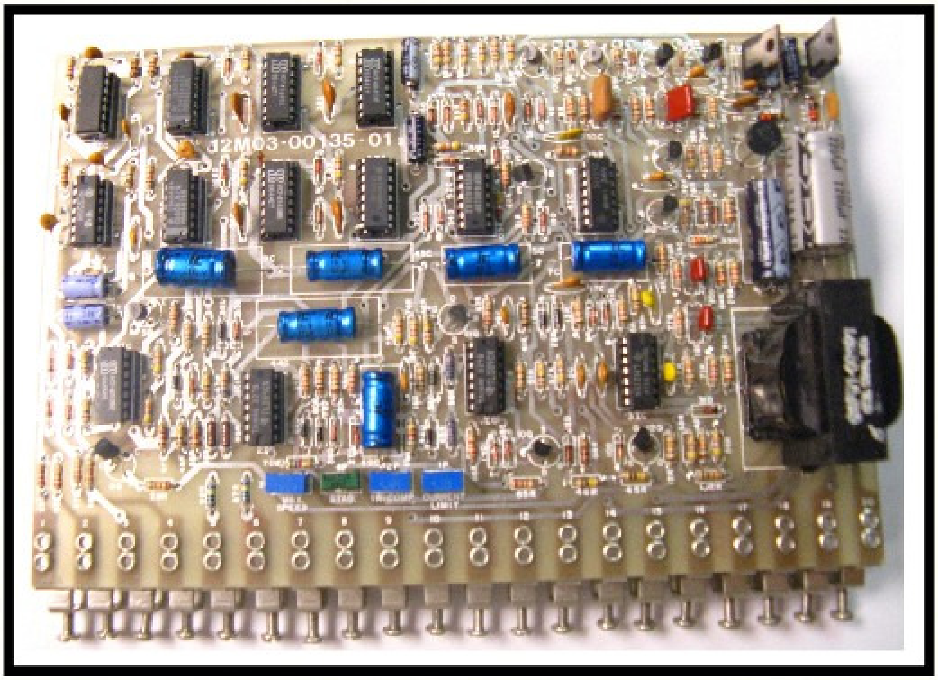
Trouble-shooting Manual
MODEL 245 REGENERATIVE FIRING CIRCUIT
PART NUMBER 12M03-00135-01



BENCH TEST

TEST MATERIAL REQUIRED:

1 – Dual Trace Oscilloscope (Tektronix 2213 or equal)
1 – DVM (Beckman HD-110 or equal)
1 – 5K Potentiometer
1 – 47K Resistor
1 – 22K Resistor
1 – 10K Resistor
1 – 6.8K Resistor
1 – 115V AC Line Cord with spade lugs one end
1 – 100-300V DC Power Supply
8 – Clip Leads

1. Connect a jumper between terminal 9 and 10. Connect the CW end of 5K potentiometer to terminal 14, CCW end to terminal 15 and wiper to terminal 7. Connect a 6.8K resistor between terminal 11 and terminal 12. Connect a 10K resistor between terminal 13 and terminal 18. Connect a 22K resistor to terminal 13 and leave the other end open. Connect a 47K resistor between terminals 9 and 8.
2. Turn Max Speed and Current Limit potentiometers full CW. Turn IR Comp and Stability full CCW.
3. Apply 115V AC to terminals 19 and 20.
4. Connect the oscilloscope to terminals 1 and 2 with common on terminal 18. No pulses should be observed.
5. Jumper the loose end of the 22K resistor to terminal 14. A single pulse 16.4 milliseconds apart should appear on both channels. Now remove the jumper.
6. Jumper terminals 16 and 17. A series of pulse trains should appear — 8.4 milliseconds long with 8 milliseconds between.
7. Jumper the loose end of the 22K resistor to terminal 15. All the pulses should disappear. Now remove the jumper to terminal 15.
8. Turn the 5K potentiometer CCW to center. The number of pulses in the train should decrease to zero. Return the potentiometer to full CW.
9. Turn the Current Limit potentiometer CCW until the number of pulses decreases to zero. The potentiometer should be about 10% from full CCW. Return the potentiometer to full CW.
10. Apply 170V DC with positive to terminal 6 and negative to terminal 5. Turn the Max Speed potentiometer CCW until the number of pulses decreases to zero. The potentiometer should be about 20% from full CW. Now return to full CW.
11. Increase the DC voltage from 170V DC to 250V DC, all the pulses should disappear.
12. Turn off the DC power supply and reverse the polarity. Connect the oscilloscope to terminals 3 and 4, and turn the 5K potentiometer full CCW. Two pulse trains should be observed. Turn the DC power supply up to 250V DC. All the pulses should disappear.
13. Switch the 170V DC power off and wait 1 second. Reapply the 170V DC while watching the pulses. The number of pulses should decrease momentarily then return.
14. Turn the Stability potentiometer full CW and repeat step 10. This time the pulses should decrease more rapidly than in step 10 and may disappear totally before recovering to normal.
15. Turn off and remove the DC power supply. Observe pulse trains on terminals 3 and 4. Jumper the open end of the 22K resistor to terminal 14. All the pulses should disappear.
16. Connect the oscilloscope to terminals 1 and 18 (common). Observe one pulse every 16.4 milliseconds. Turn the 5K potentiometer CW until another pulse appears in sync with the fixed pulse. Turn the IR Comp potentiometer full CW. The pulse should advance 3 milliseconds (nominally) from the fixed pulse.

GEMINI MODEL 245 REGENERATIVE FIRING CIRCUIT

PART NUMBER 12M03-00135-01
SCHEMATIC DIAGRAM 12M03-00135-01

I. SPECIFICATIONS

SUPPLY:

- 120 Volts AC ± 10%
- 50/60 Hz, single phase

AMBIENT TEMPERATURE:

- 0° to 40°C (32° to 104°F)
- 50°C in cabinet

INPUTS:

- To Current Regulator:
  Reference: 0 to positive or negative 6 volts DC into a Current Limit Potentiometer at terminal 10 or ±1mA into an op-amp summing junction at terminal 12.

  Current Feedback: 0 to positive or negative 2 volts DC into terminal 13 at the desired maximum current.
- To Speed (Voltage) Regulator:
  Reference: 0 to positive or negative 6 volts DC at terminal 7 or 0 to ±1mA into op-amp summing junction at terminal 8.

  Voltage Feedback: 0 to 180 volts DC nominal at terminals 5 and 6. NOTE: must always be connected for proper circuit operation, even if voltage feedback is not used.

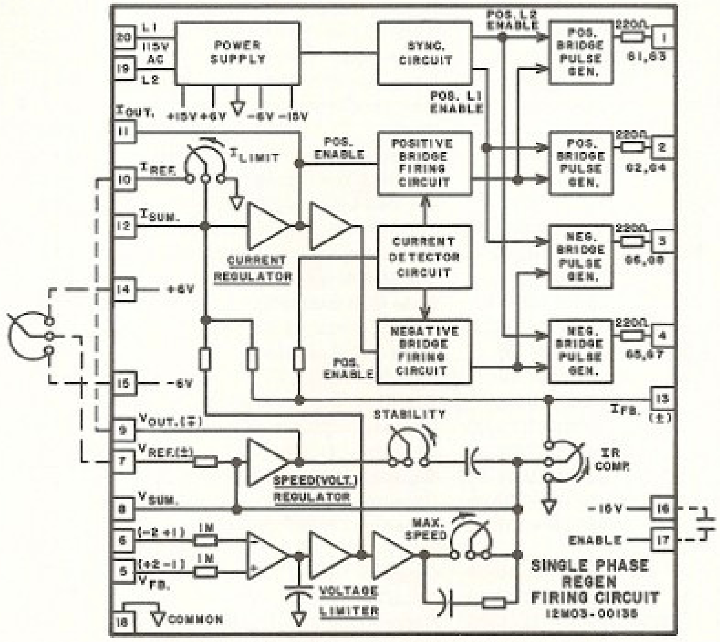


FIGURE 1. SIMPLIFIED SCHEMATIC

OUTPUTS:

- Voltage Regulator Output: 0 to ± 7 volts nominal at terminal 9, usually connected to terminal 10 as the Current Regulator Reference.
- Four pulse outputs, two for the positive and two for the negative bridges. Each pair of outputs is for alternate half cycles of the AC supply. Outputs cannot be connected directly to the thyristors, but must be isolated and amplified as required.
- Pulse output is 0 to 12 volts open circuit nominal with a 220 ohm output resistance.
- Positive and negative regulated 6 volts are available at terminals 14 and 15 respectively as reference signals.

ADJUSTMENTS:

- Stability
- Maximum Speed
- Current Limit
- IR Compensation

GENERAL SPECIFICATION:

The Reflex® Regenerative Firing Circuit is designed to control the outputs of single phase dual bridge thyristor circuits that are capable of four quadrant operation such as the Reflex® Model 253. The basic circuit is a current regulator, with optional features of voltage feedback with IR drop compensation for use as a simple speed controlled DC Motor Drive. Additional input terminals are provided for use in more complex systems, or for control of other variables such as Torque or Position.

II. THEORY OF OPERATION

Any four quadrant single phase thyristor controller requires certain basic elements to function properly without damage to itself or the connected load. These are:

1. The circuit must be able to differentiate between the two half cycles of the AC line waveform. This is similar to phase sequence in a three phase system.
2. The power circuitry consists of two separate supplies whose outputs are connected together with opposite polarities. Attention must be directed towards preventing both supplies being active at the same time. If this condition exists it represents a line-to-line fault at the AC supply, commonly referred to as a "shoot through." A "shoot through" results in destructive currents which at least open line fuses, shutting down the supply, and at most destroy the thyristors. A large part of the circuitry provided is designed to prevent "shoot throughs."
3. During circuit operation in a regenerative mode with continuous conduction, it becomes necessary to transfer or commutate the load current from one pair of thyristors to another pair. If this is not accomplished, a condition known as "Inversion Fault" or "Commutation Failure" occurs. Under these circumstances excessive voltage is applied to

the load with corresponding excessive load current. While this excessive current may not be destructive, it does interfere with normal operation.

Prevention of such faults is generally accomplished by including an "End Stop" firing signal near the end of each half cycle. Operation at discontinuous conduction where the armature current goes to zero during each half cycle, as occurs with light loading at high speeds, is not compatible with such as End Stop Pulse. Correct design procedures therefore require that the End Stop signal appears only during continuous conduction.

4. A DC motor operating at zero or light loads acts very much like a capacitor, and can "charge" up to the peak voltage of the AC wave. The single phase converter, however, cannot regenerate more than the average DC value of the AC voltage. Therefore a transition between motoring at no load with terminal voltage at the peak of the AC waveform, to regeneration can result in excessive uncontrolled currents. Again this is usually not destructive but could result in blown fuses or torque surges. Voltage limiting circuits are required to prevent this from happening.

The REFLEX® firing circuitry contains the necessary elements to avoid the problems discussed above. The control consists of the following elements as shown on the Schematic Diagram and Figure 1.

1. Power Supply
2. Synchronizing Circuit
3. Current Regulator
4. Current Detector
5. Clamps (not shown on Simplified Schematic)
6. Firing Circuits
7. Pulse Generators
8. Speed (Voltage) Regulator
9. Voltage Limiter

1. **Power Supply** — The power supply uses a center-tapped transformer with 10 volts on each side of center together with a bridge rectifier and one 2200MF and one 470MF filter capacitor to provide a nominal positive and negative unregulated 15 volts DC with respect to the transformer center-tap which is connected to circuit common.

Additionally, a regulated positive and negative 6 volts is obtained from the positive and negative 15 volt supplies using regulators 1VR and 2VR each with a 10 MF filter capacitor.

2. **Synchronizing Circuit** — The synchronizing circuit uses AC voltage from the secondary of the Power Supply transformer to generate a variety of logic signals, timed with specific relationship to the AC line. Refer to the Logic Diagram, Figure 2, for the timing details.

Transistors 3Q and 4Q receive signals from the secondary windings through resistors 1, 4, 5 and 8R and act as switches that turn on and off at the zero crossing of the AC waveform. Resistors 99R and 100R, modify the timing so that the switching action occurs slightly before and slightly after the zero crossing. Figure 2 shows these logic signals as "A" and "B."

Diodes 3D and 4D act as an "AND" gate to provide logic signal "C" also shown in Figure 2. The positive transition of logic signal "C" is detected by capacitor 30C, resistors 19R and 21R, and diode 19D. After passing through transistor 7Q and Gate 5IC(A) it becomes logic signal "C," which is a well-defined pulse occurring just prior to the end of each half cycle. This pulse will be used as the "End Stop" signal when such signal is required.

Transistors 1Q and 2Q form a switching circuit identical to 3Q and 4Q but the input to these two transistors is phase-retarded by 30 to 40 degrees because of capacitor 10C. Logic signals "D" and "E" result from the switching action. Diodes 1D and 2D act as an "AND" gate to produce logic signal "J."

Logic Signals "A" and "B" in combination with logic signals "D" and "E" are used to determine firing intervals for pairs of thyristors corresponding to alternate half-cycles of the AC waveform. Signals "A" and "D" are combined through "NAND" gate 4IC(C) to provide Logic Signal "G." Logic Signal "G" provides a measure of the entire range of permissible firing times for pairs of thyristors that can conduct during the time when line L2 is positive with respect to L1. Since this firing interval is appropriate for either the positive bridge during motoring or the negative bridge during regeneration, it is therefore provided to pulse generators for each of the two bridges through 10IC(C) and 11IC(C).

Similarly, Logic Signal "H" is derived from Logic Signals "D" and "E" to determine firing intervals when line L1 is positive with respect to L2.

Logic Signal "J" is used to reactivate a Pulse Blocking Circuit which will be described later.

3. **Current Regulator** — The current regulating amplifier 1IC(B) compares a reference signal from either the Current Limit Potentiometer, or a signal fed direct to the summing junction, to a feedback signal of nominally 2 volts at terminal 13. The amplified error between these two signals appears at pin 7 and becomes the input to the Positive Bridge Firing circuit. Amplifier 1IC(C) acts as an inverter to provide a signal of the opposite polarity to the Negative Bridge Firing circuit. This arrangement provides "push-pull" signals to the two firing circuits so that when either firing circuit is given a signal to advance the firing of its bridge, the other firing circuit receives a corresponding signal which retards its firing. This is one of several basic methods of minimizing "shoot throughs."

To allow operation of the Current Regulator, a negative 15 volts from any source with respect to circuit common must be applied to terminal 17. When this voltage is removed, field-effect switching transistor 11Q conducts, clamping the output of the current regulator to zero.

4. **Current Detector** — The same signal used as current feedback is also used to detect which bridge, if any, is conducting. The filter consisting of 58R and 7C eliminates any high frequency noise signals and also provides a slight delay to the current signal which "fools" the Current Detector into believing that the current is still flowing for a slight period after it is stopped.

After filtering, the signal is amplified by a factor of 10 to 1 and provided to comparators 3IC(A) and (C). The output of these comparators provides logic signals which indicate bridge output currents in either direction. The use of these logic signals will be described below.

5. **Clamps** — During a transition between motoring and regenerating, the load current, depending on inductance, may continue to flow for several milliseconds before decaying to zero. During this transition period, there are portions of the AC supply waveform where firing the other bridge could result in a "Shoot Through." Accordingly the firing pulses are suppressed during this time. The Current Regulating amplifier, unless similarly suppressed, would change its output during this period in accordance with the input signals, and would attempt to fire the other bridge, probably very early in the firing period. If the pulse suppression were suddenly removed at this point, the new bridge could fire "full-on," causing a large current surge.

   FET clamp transistors, 10Q and 12Q, are arranged so that in the presence of load current in either direction, the Current Regulating amplifier is allowed freedom of output changes only in the polarity that corresponds to the direction current is flowing. This means that load current can be raised or lowered as necessary, but that the amplifier cannot deliver output voltage in a direction that would fire the other bridge thyristors until the current in the conducting bridge has dropped to zero. These FET switches respond to the logic output of the Current Detector.

6. **Firing Circuits** — Each firing circuit consists of two parts—a Voltage Controlled Oscillator and a pair of Digital Counters. Each firing circuit is designed to work with one of the bridges, either positive or negative. Because the range of possible firing angles extends for more than one-half cycle of the AC Waveform, it is necessary to have a separate pulse-generating circuit for each half-cycle. The Digital Counters perform this function. The Voltage Controlled Oscillator delivers pulses to both Counters simultaneously.

   For example, the Oscillator for the Positive Bridge contains 3IC(D) and 9Q with an assortment of passive components. The output of this oscillator goes to two digital counters, 6IC and 7IC, each of which is only allowed to count for a period of time determined by logic signals "F" or "H." Since both counters receive the same pulse train input there is total balance of firing angles for both half cycles. When a counter is full it delivers a firing pulse to the appropriate pulse generator.

   The pulses for firing the Negative Bridge are generated similarly by an Oscillator containing 3IC(B) and 8Q and counters 8IC and 9IC.

   "AND" Gates 10IC(A) and (B) and 11IC(A) and (B) work to provide pulses from either the Counters described above, or from the "End Stop" pulse generator with its output signal "C." This End Stop Pulse is only permitted to pass through "NAND" gates 4IC(A) or (B) when current is flowing in the appropriate bridge as determined by the logic outputs of the Current Detector. In the absence of load currents the End Stop Pulse does not pass through to the Pulse Generator for either bridge. If current is flowing in a given bridge at the time the End Stop Pulse appears, then the End Stop Pulse is passed through to the pulse generators for that bridge to insure commutation from one half of the bridge to the other. This avoids the "Inversion Fault" and still allows operation past 180º when current is not flowing.

7. **Pulse Generators** — The Pulse Generator consists of a dual timing circuit connected as two one-shot multivibrators. Each Bridge has one dual IC, 13IC for the Positive Bridge and 14IC for the Negative Bridge, using each section for one of the half-cycles of the AC waveforms.

   Synchronizing signals "G" and "I," as described in the synchronizing discussion, are used to enable either section of the dual timer. Each of these synchronizing signals passes through an "AND" gate whose other input is an enable logic signal from dual "D" type flip-flop, 12IC. The two halves of 12IC are connected between the output of one dual timer and the "enable" of the other dual timer, through "AND" gates, 10IC and 11IC. When either Pulse Generator produces a pulse at any time during its firing interval, this pulse sets its flip-flop so that the enable logic signal to the other bridge is lost. Therefore it is impossible to produce a firing pulse to either Bridge if the other one has been fired during that half cycle.

   The flip-flops are reset at the end of the firing interval by logic signal "J" working through inverter 5IC(D). If current is present at the time of reset, transistors 5Q or 6Q prevent resetting the flip-flop. Transistors 5Q or 6Q are switched on by an output from the Current Detector, thus the non-conducting bridge is not only prevented from firing during the remainder of any half cycle where the other bridge has been fired, but also in the next half cycle if the fired bridge current has not dropped to zero by the end of the firing interval.

8. **Speed (Voltage) Regulator** — The Speed Regulator is a conventional regulating circuit that compares a zero to positive or negative 6 volts reference input at terminal 7 to an armature voltage feedback signal developed by amplifiers 2IC(C) and (D). Amplifier 2IC(D) is a differential isolation amplifier that allows measurement of armature voltage with high common-mode rejection at an impedance level of one megohm.

   IR Compensation is provided to increase the armature terminal voltage under load while motoring and to reduce it while regenerating in order to maintain relatively constant speed.

   CAUTION: The armature voltage input at terminals 5 and 6 must be connected even if the internal speed regulator is not being used, similarly, the current feedback signal at terminal 13 is necessary even if IR compensation is not required.

9. **Voltage Limiter** — In addition to providing feedback to the Speed Regulator, the signal proportional to armature voltage at pin 8 of 2IC(C) is used to limit the maximum voltage which the bridge will deliver while motoring in either direction.

   If the signal at pin 8 of 2IC(C) exceeds 6.8 volts nominal the zener diodes 5ZD or 6ZD start conducting and provide a signal to the Current Regulator which reduces its output. This function prevents the buildup of armature voltage to an excessive level at light loads.

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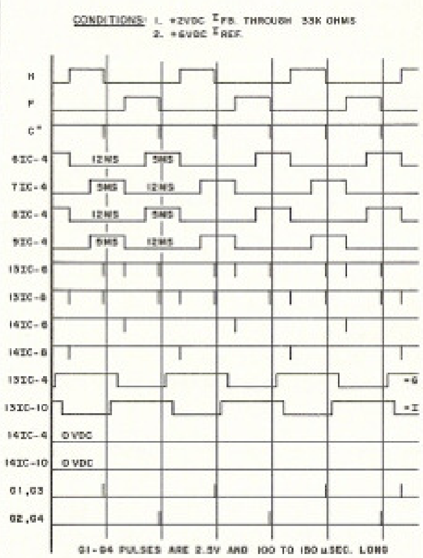
Symbol	Part #	Description (Acceptable Substitute) *
1T	04P01-00001	Transformer-120V AC PRI, two 10V SEC @ 50mA (Signal-PC20-220)
1REC	05P01-00003	Rectifier Bridge - 50V, 1A (EDI-PF50)
1-37D	05P02-00001	Diode, Signal - 50mA, 200PIV (1N4148)
1-8ZD	05P03-00005	Zener Diode - 6.8V, 500mW
1-7Q	05P04-00002	Transistor, NPN, Small Signal (2N3392)
8,9Q	05P04-00001	Transistor, PNP, Small Signal (2N3638A)
10-12Q	05P05-00001	Transistor, N Channel JFET (2N4093)
1VR	05P08-00006	Positive 6 Volt Regulator (7806)
2VR	05P08-00007	Negative 6 Volt Regulator (7906)
1,2IC	05P08-00002	Quad Op-amp, BIFET (TL-084CN)
3IC	05P08-00004	Quad Comparator (National LM339)
4IC	05P09-00011	Quad NAND Gate (4011)
5IC	05P09-00001	Quad NOR Gate (4001)
6-9IC	05P09-00004	Binary Counter, 12 Bit (4040)
10,11IC	05P09-00006	Quad AND Gate (4081)
12IC	05P09-00007	Dual Flip-Flop (4013)
13,14IC	05P08-00008	Dual Timer (National LM556)
1C	03P01-22201-00	Capacitor - 2200MF, 16V, Electrolytic
2C	03P01-47102-01	Capacitor - 470MF, 25V, Electrolytic
3-6C	03P01-10001-00	Capacitor - 10MF, 16V, Electrolytic
7,8,42C	03P02-10002-00	Capacitor - 10MF, NP, 25V, Electrolytic
9C	03P02-10101-00	Capacitor - 100MF, NP, 16V, Electrolytic
10C	03P07-22410-00	Capacitor - 0.22MF, Film
11C	03P07-10310-00	Capacitor - 0.01MF, Film
12,13C	03P07-33210-00	Capacitor - 0.0033MF, Film
14-17C	03P06-10105-00	Capacitor - 100PF, Ceramic
18-27, 31,32C	03P06-10305-00	Capacitor - .01MF, Ceramic
28-29C	03P06-50305-00	Capacitor - .05MF, 50V, Ceramic
30C	03P06-22105-22	Capacitor - 220PF, 50V, Ceramic
33-37C	03P06-10205-00	Capacitor - .001MF, Ceramic
38-39C	03P06-10005-00	Capacitor - 10PF, Ceramic

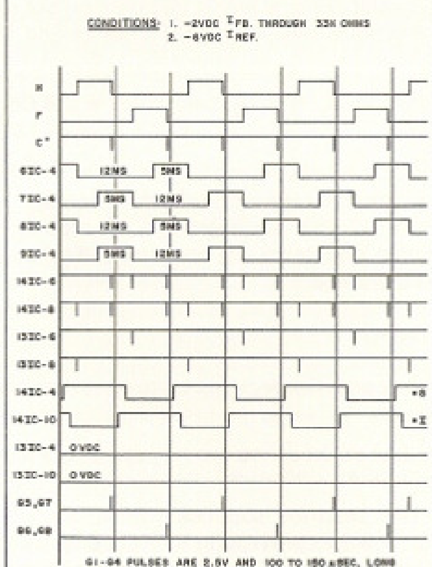
Symbol	Part #	Description (Acceptable Substitute) *
40,41C	03P01-25001-00	Capacitor - 25MF, 16V, Electrolytic
43-44C	03P02-50001-00	Capacitor - 47MF, NP, 16V
1-20,90R	01P01-10300-02	Resistor - 10K, ¼W, 5%
21,22, 25-30R	01P01-22300-02	Resistor - 22K, ¼W, 5%
23,24, 31-42R	01P01-47300-02	Resistor - 47K, ¼W, 5%
43-44R	01P01-33000-02	Resistor - 33 Ohm, ¼W, 5%
45-54R	01P01-10400-02	Resistor - 100K, ¼W, 5%
55-57R	01P01-47100-02	Resistor, 470 Ohm, ¼W, 5%
58-60R	01P01-10100-02	Resistor - 100 Ohm, ¼W, 5%
61R	01P01-18100-02	Resistor - 180 Ohm, ¼W, 5%
62,95-98R	01P01-22100-02	Resistor - 220 Ohm, ¼W, 5%
63,64R	01P01-33100-02	Resistor, 330 Ohm, ¼W, 5%
65-68, 93R	01P01-22200-02	Resistor - 2.2K, ¼W, 5%
69,70R	01P01-56200-02	Resistor - 5.6K, ¼W, 5%
71,72R	01P01-27200-02	Resistor - 2.7K, ¼W, 5%
73,74R	01P01-47200-02	Resistor - 4.7K, ¼W, 5%
75,76, 99-101R	01P01-68200-02	Resistor - 6.8K, ¼W, 5%
77,78R	01P01-82300-02	Resistor - 82K, ¼W, 5%
79,82R	01P01-12300-02	Resistor - 12K, ¼W, 5%
83,84R	01P02-10020-01	Resistor - 10.0K, ¼W, 1%
85,86R	01P02-22120-01	Resistor - 22.1K, ¼W, 1%
87,88R	01P02-10040-01	Resistor - 1.0M, ¼W, 1%
91,92R	01P01-10200-02	Resistor - 1K, ¼W, 5%
94R	01P01-33200-02	Resistor - 3.3K, ¼W, 5%
102R	01P01-15300-02	Resistor - 15K, ¼W, 5%
103R	01P01-22400-02	Resistor - 220K, ¼W, 5%
1-3P	02P04-10301-00	Potentiometer-10K, ½W (Beckman-72XR10K)
4P	02P04-50301-00	Potentiometer-50K, ½W (Beckman-72XR50K)

Note: No 89R

* OR EQUAL



WAVEFORMS FOR SINGLE PHASE REGEN FIRING CIRCUIT
12M03-00135



WAVEFORMS FOR SINGLE PHASE REGEN FIRING CIRCUIT
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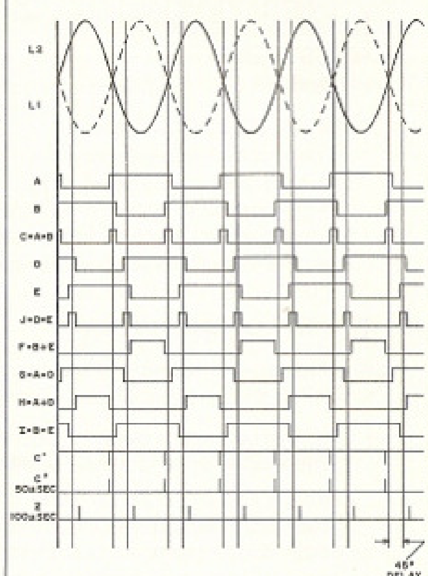
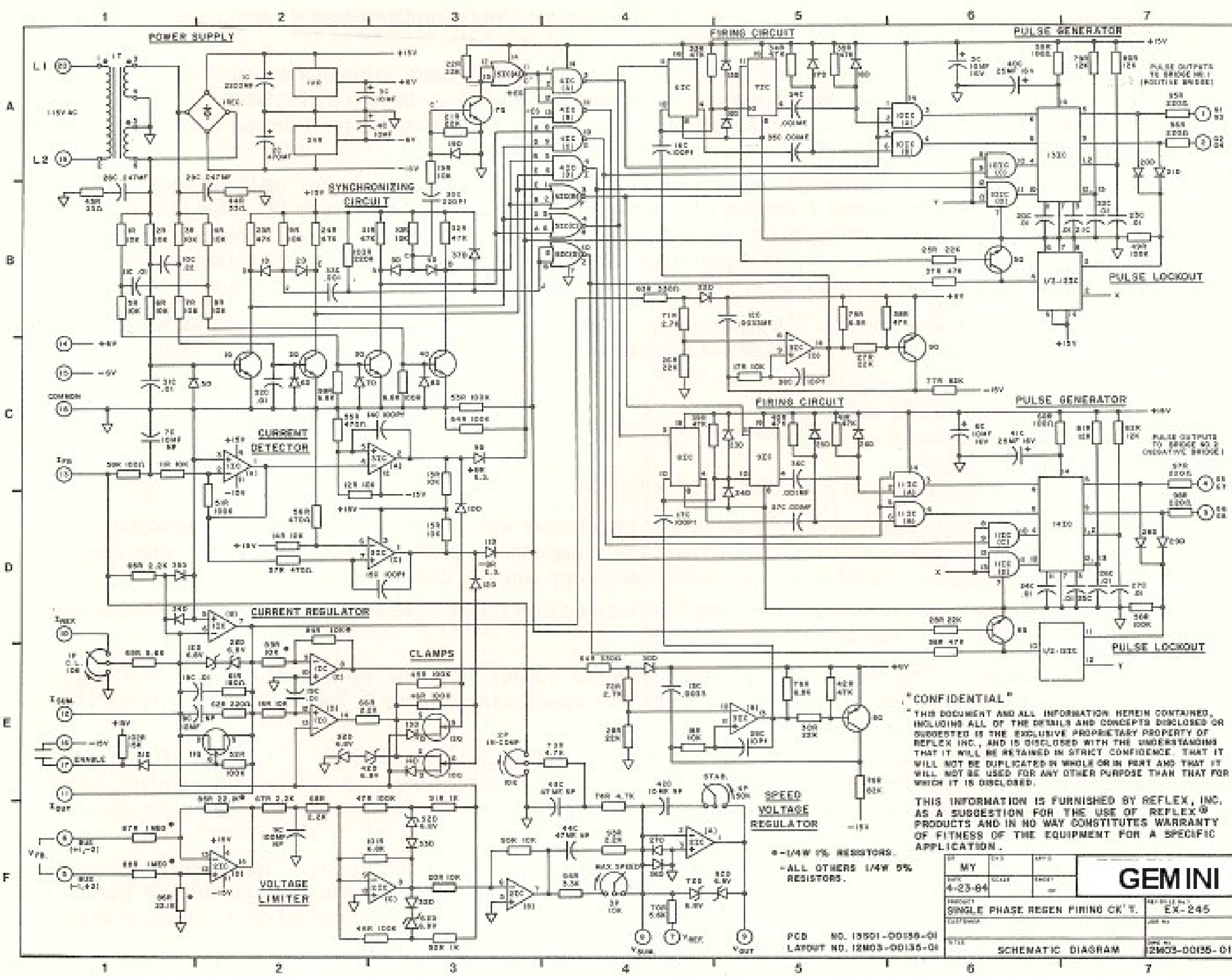


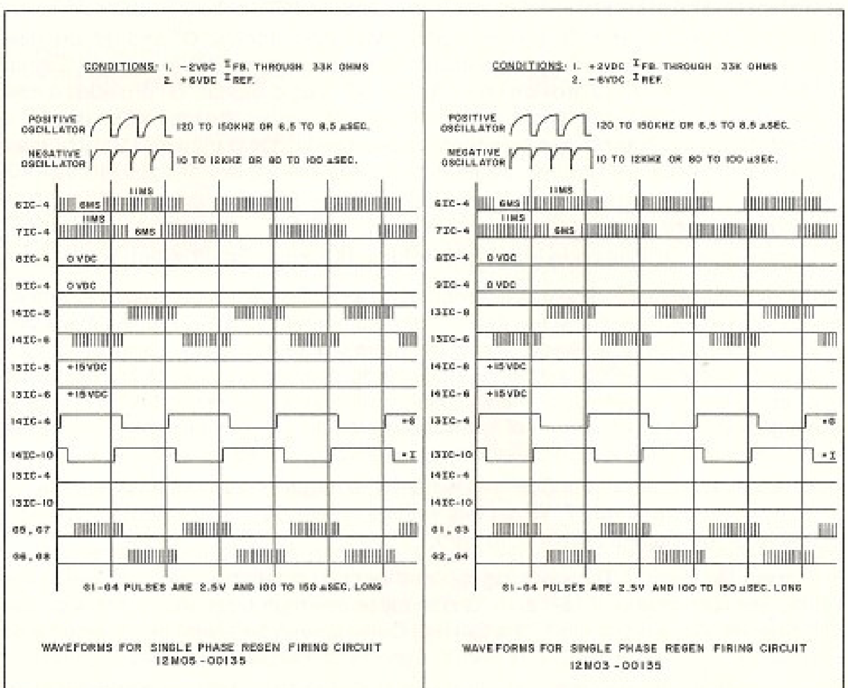
DIGITAL LOGIC FOR SINGLE PHASE REGEN FIRING CIRCUIT 12M03-00135

MODEL 245 **FIGURE 2**



VOLTAGE CHECK

1. The primary voltage of 1T, leads 1 and 2 (terminals 20 and 19), should be 120V AC.
2. The secondary voltage of 1T, leads 3 to 4 and leads 5 to 6 should be 10V AC. These can be measured between circuit common, terminal 18 (leads 4 and 5), and each AC input to the bridge rectifier 1REC (leads 3 and 6). Voltage at the AC input to the bridge rectifier 1REC should be 20V AC.
3. +15V DC nominal between the positive end of capacitor 1C and terminal 18 (common).
4. –15V DC nominal between terminal 16 and 18 (common).
5. +6V DC nominal (5.5 to 6.5V) between terminal 14 and 18 (common).
6. -6V DC nominal (5.5 to 6.5V) between terminal 15 and 18 (common).
7. Use an oscilloscope to verify that the digital logic signals appear as in Figure 2.



MODEL 245 **FIGURE 2**