# TIMING CONTROL

## DESCRIPTION

The purpose of the Timing Control circuit is to control the Inverter turn on and turn off when commercial 115vac is lost and restored respectively.

The circuit is designed to turn the Inverter on 2 minutes after a commercial power loss is sensed. The 2 minute turn on delay compensates for commercial power dips, sags, and very brief outages that would otherwise cause the Inverter to false or rapidly turn on and off.

Conversely, the circuit is designed to turn the Inverter off 5 minutes after commercial power restoration is sensed. The 5 minute delay prevents false turn off if restoration is not permanent. It also holds the Inverter on line until commercial power stabilizes immediately after restoration.

The Timing Control circuit is part of the 1A1 Timer-Low Batt Disconnect PCB. Commercial power line sensing is provided by an off-board chassis mounted module. The timing circuits control the Main Relay which applies and removes battery power to the Inverter. The Main Relay is off-board chassis mounted.

Loss and restoration of power is sensed by the Timer Line Sense Module. The Timer Line Sense Module contains a relay that is powered via commercial 115vac. This relay is normally energized when 115vac is present and de-energizes when 115vac is lost. The Timer Line Sense Module provides relay closure inputs to trigger the Timing Control circuits.

The 2 minute timer is designed around a UJT utilizing an RC time constant to determine the 2 minute time out. With a loss of power the 2 minute timer begins timing out. After 2 minutes the output of the UJT timer triggers an SCR to the on state. With the SCR turned on, the Main Relay energizes applying battery power to Inverter.

The 5 minute timer is designed around an IC 555 timer. When commercial power is restored the 5-minute timer begins to time out.

Upon completion of the time out, a trigger is developed which momentarily triggers the Main Relay Output Transistor off. This de-energizes the Main Relay removing battery power from the Inverter. Turning off the Main Relay Output Transistor also breaks the "keep alive" current path for the SCR turning it off. With the SCR turned off, the Main Relay remains de-energized.

The Timer Control circuits are supplied voltage from a switched 9.6 voltage source with the exception of the output driver transistor. The 9.6 volts is a regulated supply voltage sourced from the battery. The output driver transistor is supplied with a fused/filtered 13.4 volts directly from the battery to ensure enough drive to the Main Relay Output Transistor and ultimately ensure the Main Relay energizes with a loss of commercial 115vac. The 9.6 volt supply is switched through the Low Battery Disconnect Relay (see Low Batt Disconnect schematic). If battery voltage falls below 11.5 volts, switched 9.6 volts will be removed de-energizing the Main Relay and removing battery power from the Inverter. This prevents deep discharge and possible damage to the battery. Timer circuit supply voltage is sourced from the battery due to the need to have the timing circuits operating even with the loss of commercial 115vac.

## DETAILED THEORY OF OPERATION

### Circuit Description

2 Minute timer:
Q6 is a Unijunction Transistor. R10, R11, and C6 are the time constant components that set the 2 minute timeout of Q6. R12 limits current flow through Q6 when it's conducting. R13 develops the output voltage when Q6 conducts. R14 sets the gate current for SCR Q7 and C7 is a coupling capacitor which develops the turn on spike to the SCR gate.

5 Minute Timer:
R1 serves a dual purpose. R1 applies a high to IC1 pin 4, the reset pin, enabling the timer and it charges C1, a coupling capacitor and spike producer for Q1.

R2 provides a discharge path for C1. Q1 is a switch that provides a trigger to IC1 pin 2, the trigger pin. R3 is Q1 collector load resistor. C4 is a decoupling capacitor. R4 and C3 are the time constant components that set the 5 minute timeout of IC1. C4 is a decoupling capacitor to stabilize IC1 operation. R5 is a Q2 base current limiter. Q2 serves several functions. Q2 is an output buffer for IC1, it's a phase inverter for IC1's output, and it's a driver for the trigger forming circuit consisting of R6, C5, and R7. R6 is a collector load resistor for Q2 and is the charge path for C5. C5 is a coupling capacitor which develops a turn on spike to Q3. R7 provides a discharge path for C5. Q3 is a pre-driver and phase inverter for Q4. R8 is a Q3 load resistor. Q4 is an output transistor driver. It's configured as an emitter follower to supply high current drive to Q5. R9 is a Q4 collector load resistor and sets the emitter current drive level for the output transistor. Q5 is a Darlington pair output transistor switch that energizes the Main Relay 1RY1. Relay 1RY1 is a heavy duty relay consisting of three sets of contacts. The primary contacts are made of heavy copper to conduct very heavy current flows (approximately 30 – 40 amps when the Inverter is fully loaded). Secondary contacts consist of a normally open set and a normally closed set that are used for secondary functions. 1D1 is used to dampen inductive kick (and prevent damage to Q5) when the relay de-energizes. 1RY1 draws between 350 and 400 ma when energized. Supply voltage for the Main Relay is via a fused line directly from the battery to ensure enough power is available to energize the relay.

### Circuit Operation

There are 3 modes of Timer control circuit operation.

1). Commercial 115vac Present, Normal Mode.
2). Commercial 115vac Absent, Inverter Mode.
3). Commercial 115vac Restored, Restoration Mode.

### Commercial 115vac Present, Normal Mode

For Normal Mode it is assumed that commercial 115vac is present and has been present for a long period of time.

Quick Summary of Circuit Condition:

Q1 off, IC1 idle (output low), Q2 off, Q3 off, Q4 on, Q5 on, Q6 off, SCR Q7 off, Main Relay 1RY1 de-energized.

Detailed Normal Mode Operation:
The Timer Line Sense Module relay is energized and the 2 minute timer contacts apply a ground to the emitter of UJT Q6. This ground prevents capacitor C6 from charging and holds Q6 in an off condition. With Q6 off, there is 0 volts on Q6 B1 terminal and thus no turn on voltage for SCR Q7. SCR Q7 is off and Main Relay 1RY1 is de-energized.

Also, with the Timer Line Sense Module relay energized, the 5 minute timer contacts apply switched 9.6 volts via R1 to pin 4 (the reset pin) of 555 timer IC1, enabling the timer. This positive voltage is blocked by coupling capacitor C1, thus Q1 is turned off, it's collector is high and pin 2 (trigger input) of IC1 is held high. IC1 is in an idle state and the output on pin 3 is low. Q2 is off and it's collector is high. Q2's high collector voltage has C5 charged, thus 0 volts is applied to Q3. Q3 is off, it's collector is high, thus Q4 is on. With Q4 on, it's emitter is high turning Q5 on. At this point, Q5 is on but SCR Q7 is off and Main Relay 1RY1 is de-energized.

### Commercial 115vac Absent, Inverter Mode

For Inverter Mode of operation, it is assumed that commercial 115vac has just been lost.

Quick Summary of Circuit Condition:

Q1 off, IC1 disabled (output low), Q2 off, Q3 off, Q4 on, Q5 on, Q6 (initially off until 2 minute timeout, then briefly on producing SCR trigger, then off again), Q7 (initially off, 2 minutes after loss of commercial 115vac on), Main Relay 1RY1 on 2 minutes after loss of commercial 115vac.

Detailed Inverter Mode Operation:
With a loss of commercial 115vac the Timer Line Sense Module relay de-energizes. With the Timer Line Sense Module relay de-energized the ground is removed from the emitter of UJT Q6 and C6 is allowed to charge through R10 and R11. After 2 minutes C6 will be charged to a level that will turn Q6 on. When Q6 turns on, C6 discharges up through R13 developing a positive voltage on Q6 B1. This positive voltage is felt through R14 and causes C7 to charge through SCR Q7 gate. R14 limits Q7 gate current to a safe level. This positive spike applied to Q7 gate causes the SCR to turn on. Q5 is already in an on condition and Main Relay 1RY1 energizes applying battery power to the Inverter. When the Main Relay energizes, it's normally open secondary contacts close applying a ground through the Timer Line Sense Module's de-energized contacts to Q6 emitter. This ground after activation disables the 2

minute timer again. This prevents the 2 minute timer from continuing to produce SCR gate triggers every 2 minutes once the Main Relay has been activated. This is done to prevent falsing once activated. If the Main Relay does not activate for some reason the 2 minute timer will continue to generate gate triggers every 2 minutes.

Also, with the loss of commercial 115vac the Timer Line Sense Module's de-energized contacts apply a ground to IC1 pin 4 (reset pin). This holds IC1 in a reset condition as soon as commercial 115vac is lost, essentially disabling the 5 minute timer. This prevents falsing that may cause the Main Relay to de-energize 5 minutes after it has energized while commercial 115vac is still absent. The 5 minute timer is held disabled throughout the Inverter Mode of operation.

The Inverter Mode of operation will be maintained as long as commercial 115vac is absent AND battery voltage is above 11.5 volts. If battery voltage falls to 11.5 volts due to prolonged Inverter Mode operation a Low Battery Disconnect detection circuit will remove switched 9.6 volts from the Timing Control circuits. With this loss of operating voltage, Q4 base drive is lost, Q4 turns off, this causes Q5 and Q7 to turn off, and Main Relay 1RY1 de-energizes thus removing battery power from the Inverter. The whole backup system will now be in low battery shutdown preventing excessive discharge damage to the battery. The backup system will remain in this condition until commercial 115vac is restored and the charger starts charging the battery. With the charger operating, switched 9.6 volts will be reapplied to the Timing Control circuits, reactivating them to Normal Mode operation.

### Commercial 115vac Restored, Restoration Mode

For Restoration Mode of operation, it is assumed that commercial 115vac has just been restored. Restoration Mode only lasts 5 minutes, after which the circuit is in Normal Mode operation.

Quick Summary of Circuit Condition:

Q1 (briefly turned on producing a trigger, then off), IC1 (in the timeout mode, output goes high for 5 minutes, then drops low), Q2 (initially on for 5 minutes, then off), Q3 (initially off, briefly triggers on after 5 minutes, then off), Q4 (initially on , briefly trigger off after 5 minutes, then on), Q5 (initially on, triggered off after 5 minutes, then on), Q6 off, Q7 (initially on, after 5 minutes off), Main Relay 1RY1 (initially energized, after 5 minutes de-energized).

Detailed Restoration Mode Operation:
When commercial 115vac is restored the timer Line Sense Module again activates energizing it's relay. With the Timer Line Sense Module relay energized, the 5 minute timer contacts apply a high via R1 to IC1 pin 4, enabling the 555 timer. This positive voltage is also applied to C1 causing it to charge through Q1 base-emitter junction. This briefly turns Q1 on until C1 is charged, after which Q1 will turn off again. Briefly turning Q1 on pulses it's collector low thus triggering the timer via IC1 pin 2. C1 is a decoupling capacitor which filters off high frequency noise and other spikes which may falsely trigger the timer.

With IC1 triggered, output pin 3 goes high, and C3 begins charging through R4. The high on pin 3 turns Q2 on through base current limiter R5. With Q2 on, C5 discharges down through R7 and up through conducting Q2. This discharge produces a negative spike on Q3 base.

Note:

> The initial rising of IC1 pin 3 high after power is restored does no real work in the remaining circuitry. It was explained above to further understand scope signals that may be seen on Q3 base. Pin 3 falling low again after 5 minutes actually performs work in the remaining circuits.

The pin 3 output will remain high until after 5 minutes C3 charges to a level that triggers the output low again (IC1 returns to an idle state). When IC1 pin 3 falls low after 5 minutes, Q2 turns off and C5 begins to charge through Q3 base-emitter junction. This briefly pulses Q3 on until C5 becomes charged and Q3 turns off again. When Q3 is pulsed on, it's collector is pulsed low, and Q4 is pulsed off. When Q4 is pulsed off, base drive to output transistor Q5 is pulsed off. This causes Q5 to pulse off, removing "keep alive" current from SCR Q7, thus turning Q7 off. This de-energizes Main Relay 1RY1 and removes battery power from the Inverter. Pulsing Q5 off de-energizes the Main Relay, turning Q7 off keeps the Main Relay de-energized. Q5 is only pulsed off after 5 minutes. It turns right back on making it ready and awaiting Q7 to be turned on again 2 minutes after a commercial 115vac loss. Additionally, when the Main Relay de-energized, it's secondary contacts holding the 2 minute timer disable return to their normally open condition. This allows the 2 minute timer to be enabled during the next loss of commercial 115vac.

Also, when commercial 115vac was restored the Timer Line Sense Module relay contacts applied a ground to the emitter of UJT Q6 holding the timer disabled until the next loss of commercial 115vac.

Once Main Relay 1RY1 has de-energized the Timing Control circuits or returned to the Normal Mode of operation.