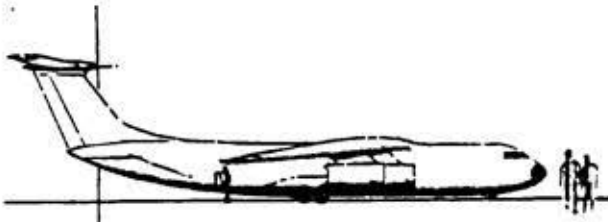


DOPPLER NAVIGATION COMPUTER

GENERAL

This computer system provides the navigator indications of distance to go to a preselected destination as well as distance from his preselected flight path (distance crosstrack). This system requires ground speed and ground track information from the Doppler radar system.

AIRCRAFT INSTALLATION

The aircraft installation diagram shows general cabling and component locations. Those components are as follows:

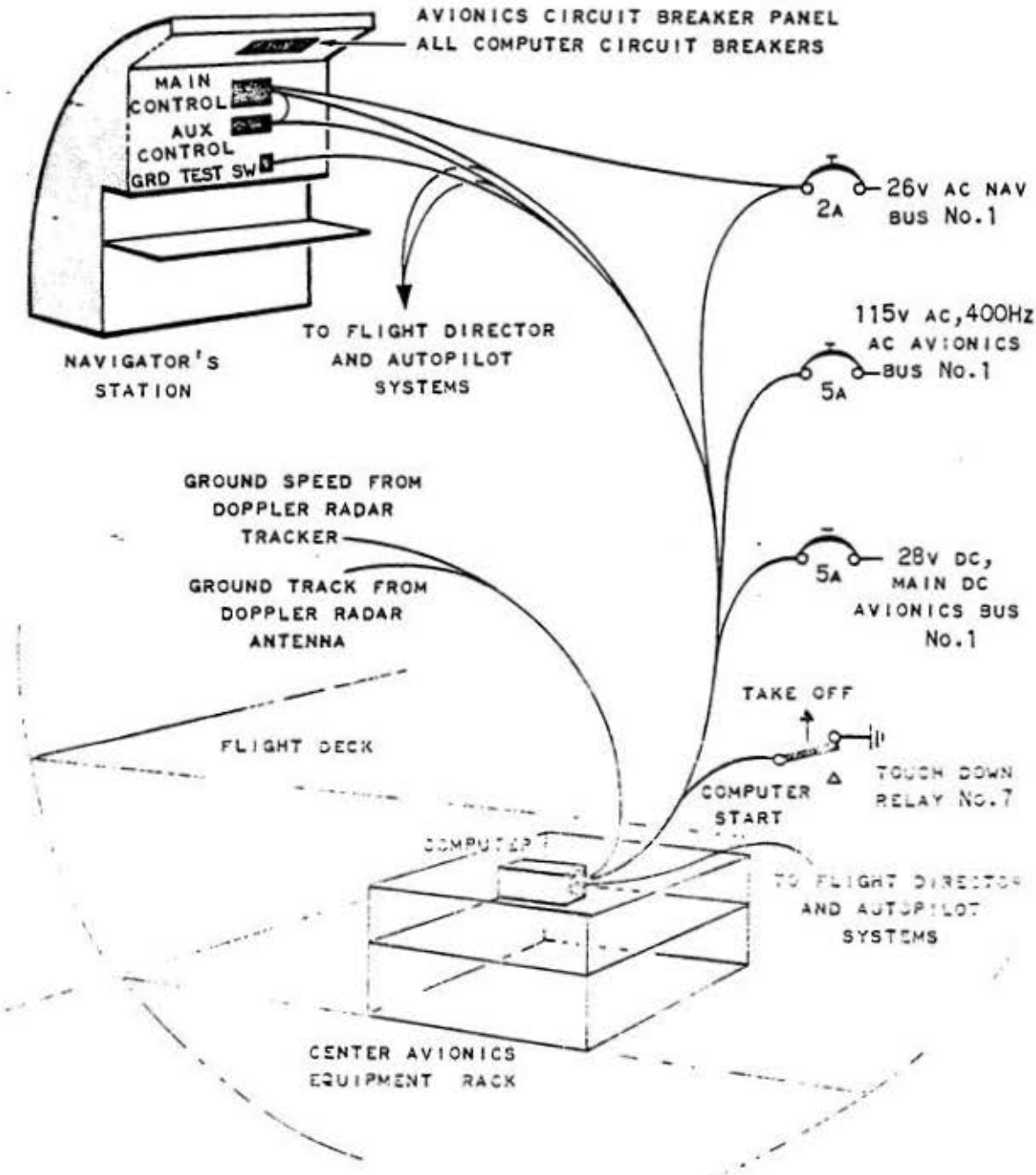
- Computer CP-622
- Main Control Panel C-3819
- Auxiliary Control Panel C-3820
- Ground Test Switch

SYSTEM OPERATION

Doppler computer operation requires Doppler radar groundspeed (audio signal at 20.66 Hz per knot in radar land mode) and Doppler radar ground track (compass heading ± drift angle).

Ground operation of the computer is only provided when the ground test switch is in "TEST" position. For inflight operation the switch must be placed to "NORMAL" before takeoff.

When the navigator determines his departure and destination points, he presets knob Ⓑ or Ⓓ on the main control panel to the desired track angle between the two points. The desired track indicators do not change with computer operation. The nautical mile distance to go between the points are preset by knob Ⓕ or Ⓖ. If he desires presetting the angle on Knob Ⓓ

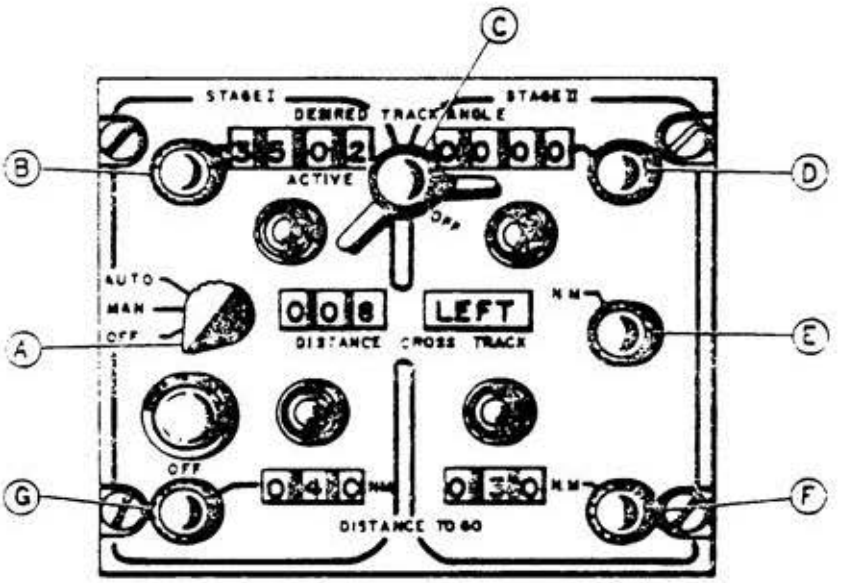


AIRCRAFT INSTALLATION

GROUND TEST SWITCH

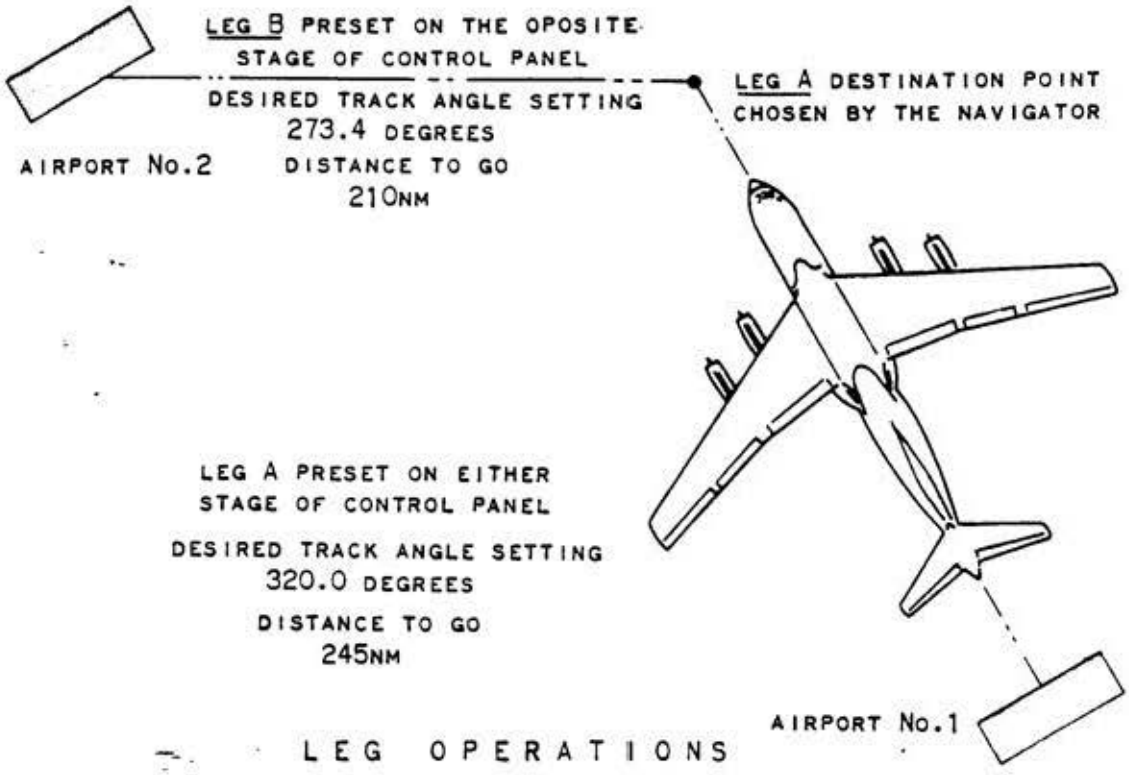
(STAGE II) he must use the STAGE II distance-to-go knob (F). Knobs (E) and (I) must be set to 000 miles crosstrack. The navigator may preset two flight legs. He determines his first leg and presets it as explained previously. His second leg may be preset in the same manner on the opposite stage.

AUXILIARY CONTROL



MAIN CONTROL

ASN-35 CONTROL PANELS



LEG OPERATIONS

For a two leg operation, as shown in the "Leg Operations" illustration, the navigator places Knob (C) to the stage he has preset for leg A and switch (J) in the "NAV" position. To activate the system, Knob (A) is placed to manual ("MAN") or automatic ("AUTO").

With the Doppler radar preslewed or operating the computer begins counting when the aircraft lifts off airport 1. With Knob (H) as shown, the main control panel CROSSTRACK indicator will constantly display the left or right nautical miles distance in tenth mile increments from the preselected leg A. The pilot will see deviation from the leg on his flight director and attempt to keep the aircraft on course. When the leg A stage counts down to 000 NM CROSSTRACK and DISTANCE-TO-GO, the navigator knows the aircraft is over the leg A destination. He then transfers stages manually with Knob (C) if Knob (A) was preset to "MAN." If "AUTO" had been preset, stage switching would be automatic when the leg A stage counted down to 000 NM distance-to-go. When the system is switched to the leg B stage the main panel will stop counting on the leg A stage and begin counting on the leg B stage. The main panel CROSSTRACK will now read distance from leg B. Accuracy of the CROSSTRACK reading for leg B will only occur if the indicator was 000 NM crosstrack upon stage switching. It is necessary therefore for the aircraft to be over destination No. 1 upon stage switching.

When the aircraft reaches airport 2 the leg B stage will read 000 NM crosstrack and 000 NM to go. If the pilot chooses to pass over airport 2 automatic stage

switching will not re-occur if the navigator leaves the previous leg A stage set to 000 NM distance to go. With knob (H) preset to "3," CROSSTRACK display for both stages reads only on the auxiliary panel. This would be required if the main panel crosstrack counter was inoperative. In position "2," the auxiliary panel displays STAGE I CROSSTRACK and the main panel will display STAGE II CROSSTRACK depending on the selected stage at the main panel. This position provides a complete set of counters for each stage.

The drop position of switch (J) increases counting speed by 10. Therefore preset valves of crosstrack and distance-to-go on the stage being preset for a drop leg must be 10 times greater than normal for "NAV" (cross country) operation to obtain 000 NM readings over the target.

SPECIFICATIONS

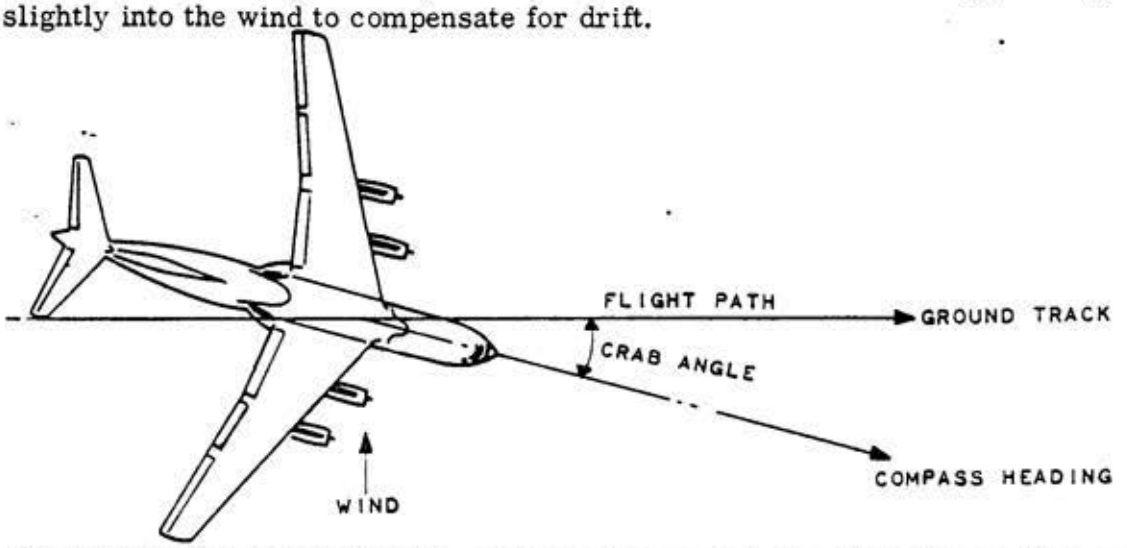
DOPPLER COMPUTER ASN-35

CHARACTERISTIC	SPECIFICATION
Power requirements	28 volts, DC 115 volts, AC, 400 Hz 26 volts, AC, 400 Hz
Maximum DISTANCE-TO-GO Readout	999 NM (99.9 NM in DROP mode) (1 NM steps in NAV 0.1 NM steps in DROP)
Maximum CROSSTRACK Readout	99.9 NM (9.99 NM in DROP mode) (0.1 NM setp in NAV 0.01 NM steps in DROP)
Desired track angle	000.0 to 359.9 degrees
Altitude	50,000 feet maximum
Ambient temperature	-55°C (-67°F) to + 55°C (+131°F)

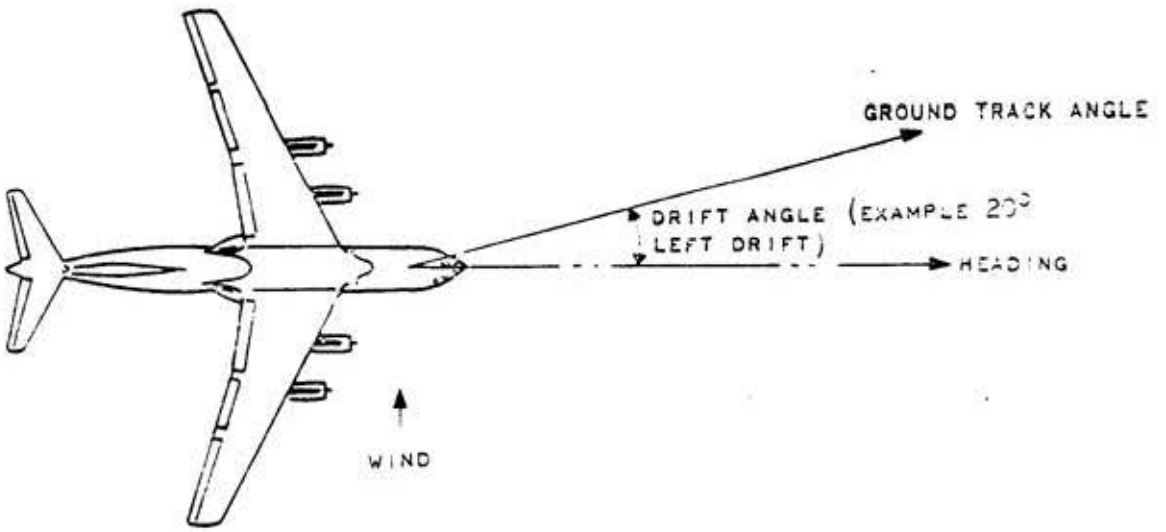
BLOCK DIAGRAM THEORY OF OPERATION

The ground track (course) information from the Doppler radar antenna is

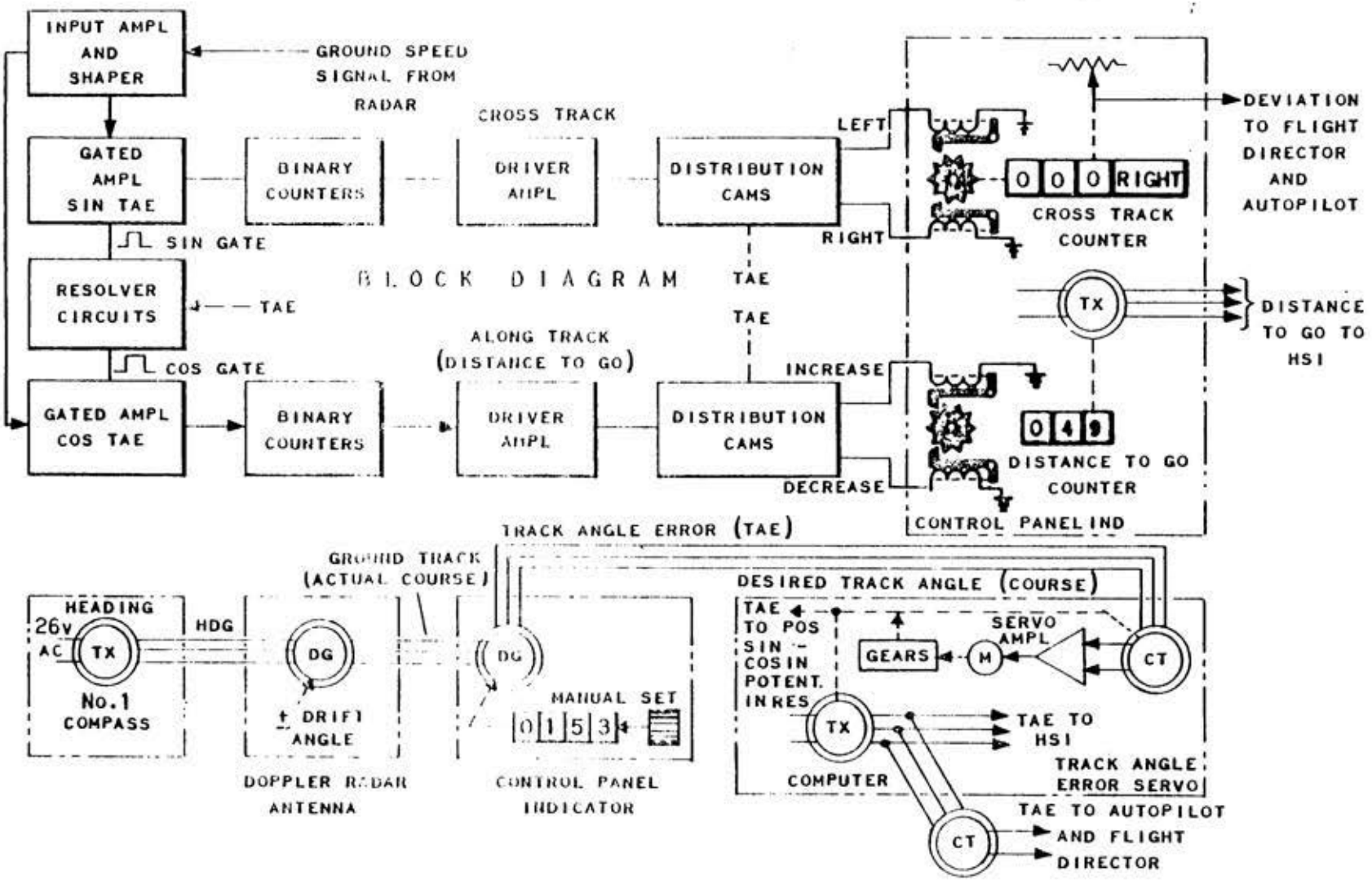
compass heading plus or minus the drift angle of the aircraft. The ground track information represents the actual path of the aircraft over the earth regardless of aircraft heading. The aircraft illustrated is crabbing (heading) slightly into the wind to compensate for drift.



If the aircraft is not crabbed to compensate for wind, it will be blown off course at the drift angle. Drift angle is therefore opposite the crab angle.



The radar ground track information representing the actual path of the aircraft is a 400 Hz 3 wire synchro signal. The track angle error loop diagram will show that the actual ground track is compared with the desired track the navigator manually selects at the control panel. The resultant signal from the Differential Generator (DG) is 3 wire, 400 Hz, representing the off course difference between the actual track and the selected track. Difference between the two is called



BLOCK DIAGRAM

TRACK ANGLE ERROR LOOP

Track Angle Error (TAE). TAE will adjust the computer for proper control panel readings for any difference (TAE) in actual course (track) and selected course (track).

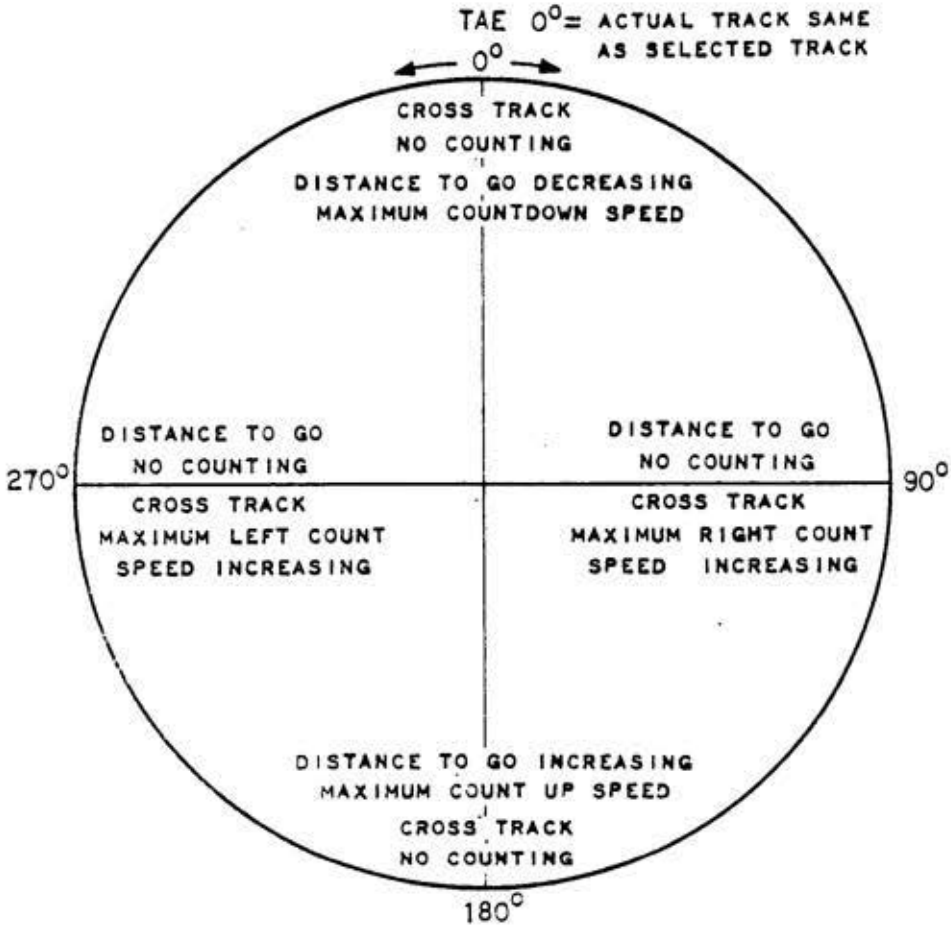
The TAE signal positions a servo in the computer. The TAE servo motor shaft positions a sine-cosine potentiometer in the resolver circuits. The sine-cosine potentiometer effectively multiplies the Doppler ground speed signal by the sine (cross track) and cosine (along track distance to go) of the TAE. When the aircraft is on course TAE is zero degrees. The ground speed signal will be multiplied by 0 (sine) and 1 (cosine). Ground speed information will drive the selected stage distance to go counter at the rate determined by the cosine ground speed. No cross track counting will occur. When the aircraft is not on course, TAE will occur multiplying the ground speed signal to the distance to go circuits by a cosine less than 1 slowing the distance to go countdown.

Cross track (LEFT or RIGHT) will occur at a rate determined by off course flight (TAE) because the ground speed to the cross track circuits is multiplied by a sine more than O. If the aircraft course is to the right of the desired course (clockwise TAE) RIGHT CROSS TRACK counting will occur. If the TAE is counterclockwise LEFT GROSS TRACK counting will occur.

Since TAE results from off course conditions the TAE illustration shows the control panel counting for four TAE angles. At intermediate angles the ground speed must be multiplied by the sine and cosine of the TAE to determine rate of [illegible]

[illegible] ground speed square wave audio signal is connected to [illegible] speed sine and cosine speed amplifiers. The turn on [illegible] these amplifiers are determined by the sine-cosine potentiometer. [illegible] number of pulses per unit of time to the aircraft travels. [illegible] the sine amplifier is [illegible] the cosine amplifier [illegible] binary counters and stored. The pulse output to the [illegible] indicator for each mile traveled in "NAV" mode and for each [illegible] in "DROP" mode.

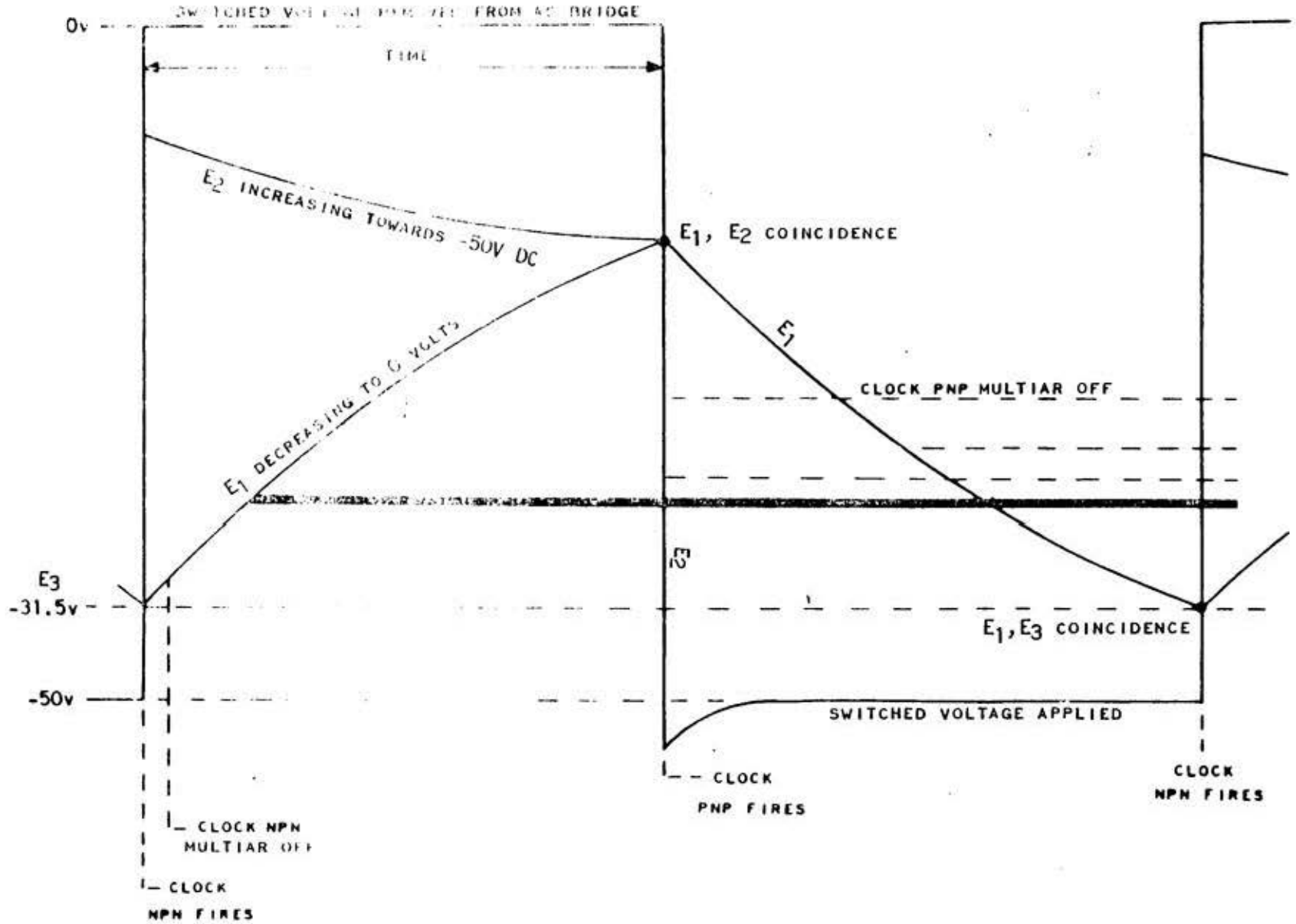
Since the sine is 0, the crosstrack binary counters receive no pulses and no cross track counting occurs. At 90 or 270 degrees TAE (cosine = 0, sine = 1) the sine amplifier is "ON", passing the pulses to the cross track binary counters which produce one pulse output to the control panel CROSS TRACK solenoid indicator for each tenth mile traveled in "NAV" mode and for each hundredth mile traveled in "DROP" mode. TAE shaft driven cam switches select the proper solenoid in the CROSS TRACK and DISTANCE TO GO indicators on the control panels.



At 0 to 90 degrees TAE the RIGHT cross track and decrease distance-to-go solenoids are selected. At 90 to 180 degrees TAE the RIGHT cross track and increase distance-to-go solenoids in the control panel are selected. At 180 to 270 degrees the LEFT and increase solenoids are selected. At 270 to 360 degrees the LEFT and decrease solenoids are selected. The choice of STAGE I or STAGE II groups of solenoids are selected at the control panel by switch C.

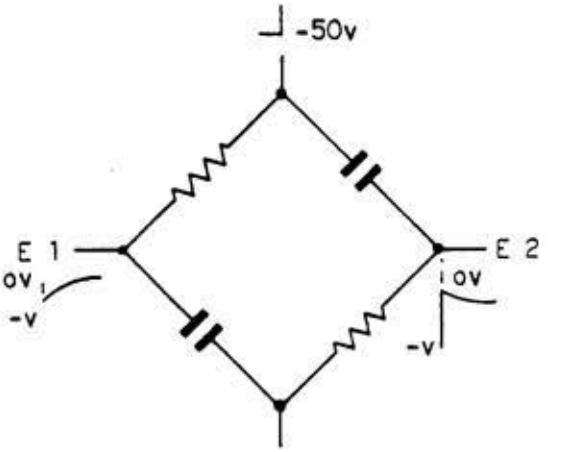
DETAILED ANALYSIS OF RESOLVER OPERATION

The ground speed frequency from the APN-147 passes through a computer start relay that is energized at lift-off. The ground speed audio frequency square wave is converted into pulses by the Schmitt trigger circuit. Pulse width is constant throughout the range of the Doppler frequencies. In order for the ground speed signal to be resolved into distance to go, a time base (clock) must be used. The clock will turn the computer counting on and off 16 times per second. An



RESOLVER CLOCK WAVEFORMS

A-C bridge is used as a clock reference. As shown on the Resolver Clock Waveforms diagram, a 50-volt, D-C switched level is removed from the bridge. Terminal E-1 is exponentially decreasing to zero volts while E-2 is exponentially increasing to a negative 50 volts. At some point in time the two voltages will coincide. A PNP clock multiar detects this coincident point and starts to oscillate. A multiar is basically a blocking oscillator whose firing point is determined by comparing two input voltages, one increasing and one decreasing at an exponential rate. The oscillation is used to operate a flip-flop which then operates a high voltage switch to reapply the minus 50-volt level. The capacitors in the bridge then are driven towards minus 50 volts. At some point in time as E-1 increases (negatively), it will coincide with a minus 31.5-volt reference (E3). An NPN clock multiar detects this coincident point and starts to oscillate, returning the flip-flop and high voltage switch to the initial condition. This process continues, generating a 16 Hz square wave clock on pulse at each cycle. The clock on half of this square wave is the active time for the computer.



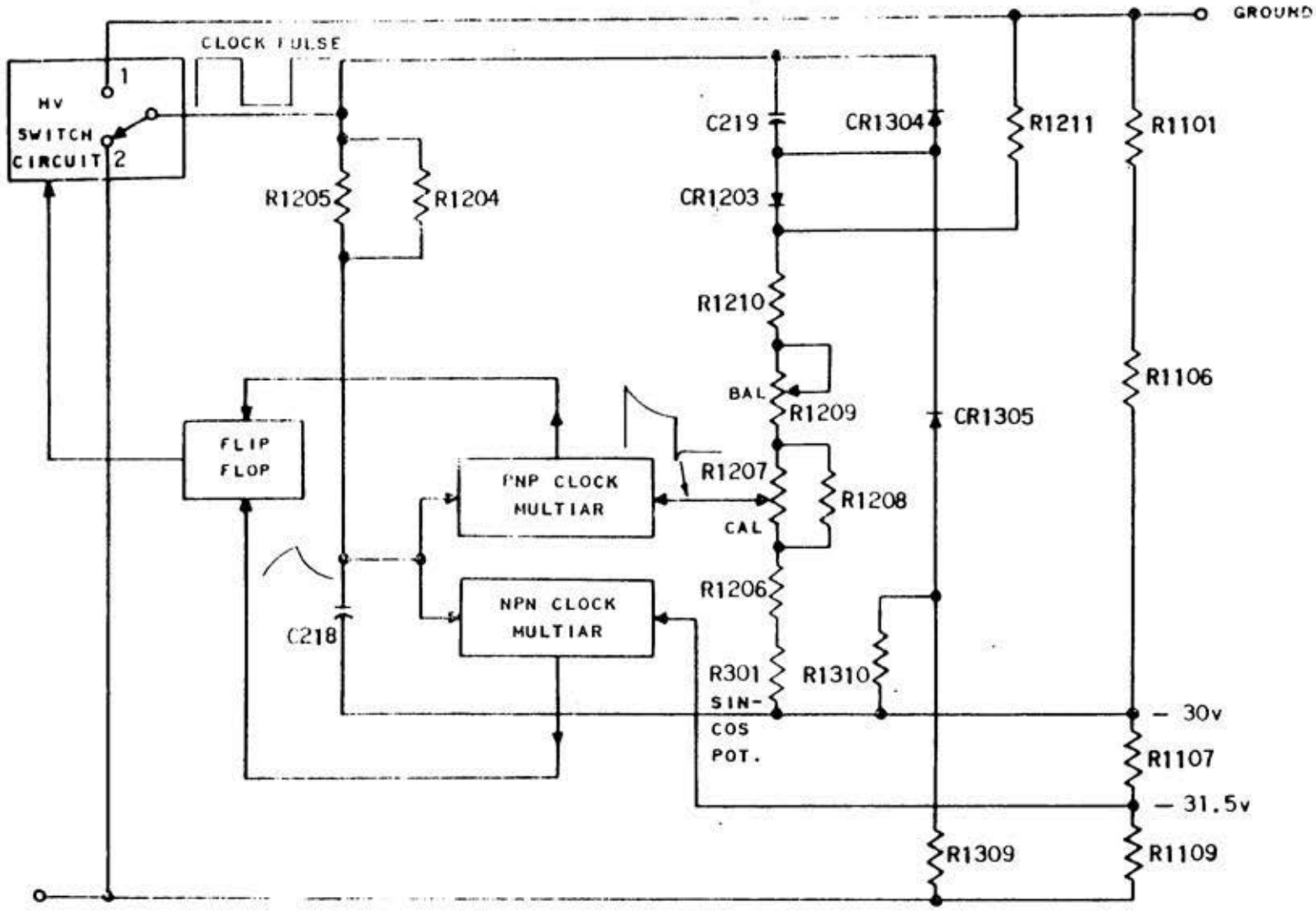
SIMPLIFIED CLOCK
A-C BRIDGE

Using the clock as a time reference the resolver will produce a fixed delay gate, a variable cosine gate, and inversely variable sine gate. The delay gate momentarily turns off the delay gated amplifier at the beginning of each clock on time to assure that the Doppler ground speed pulses reach both the cosine and sine gated amplifiers simultaneously.

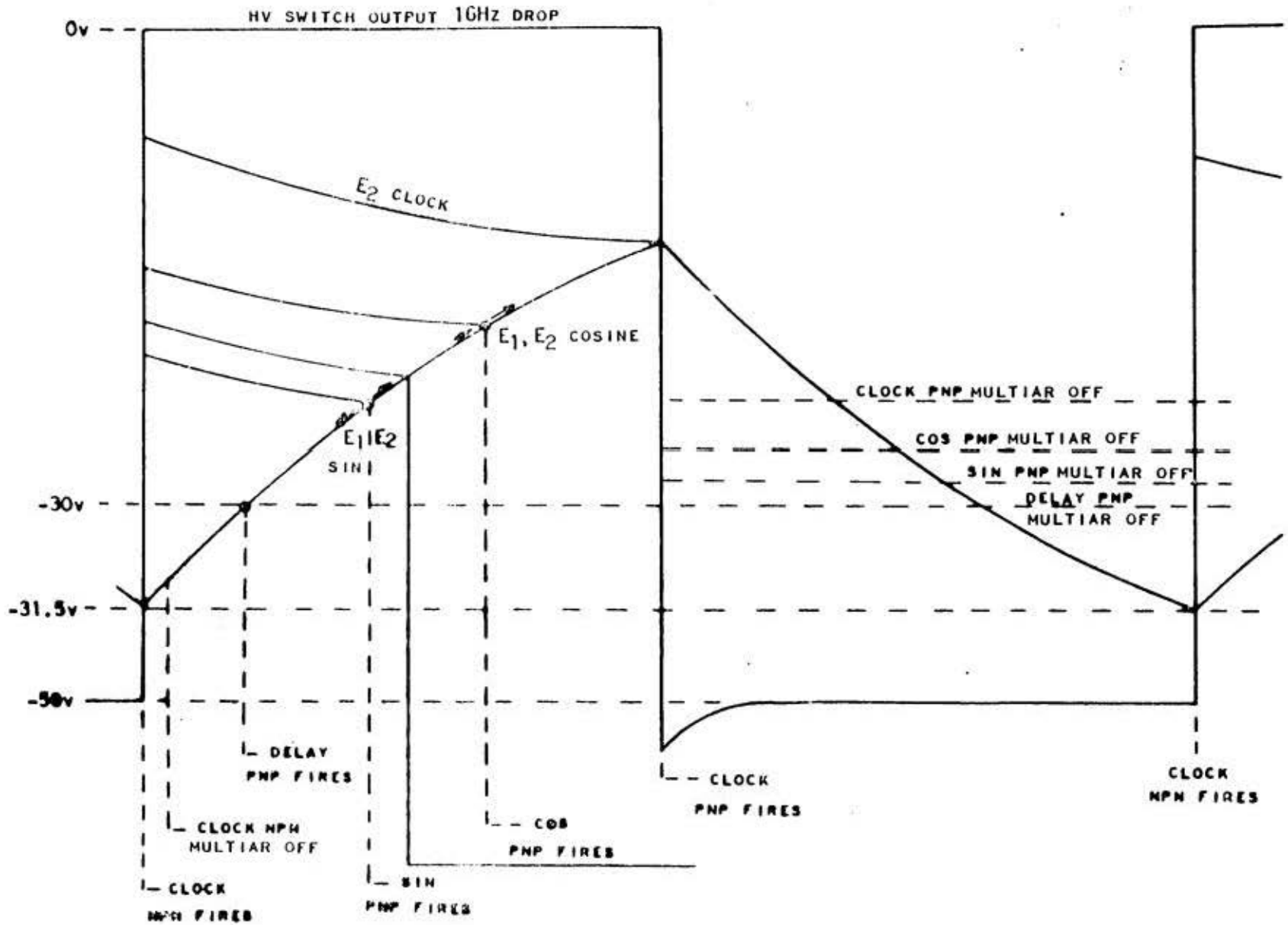
As the high voltage switch applies voltage to the A-C bridge (clock on), E-1 decreases and E-2 increases. E-1 decreases toward 0 volts exponentially from the minus 31.5-volt reference. When E-1 reaches minus 30 volts, the delay multiar oscillates, triggering the delay flip-flop ending the delay gate, allowing the delay gated amplifier to pass the ground speed pulses to the cosine and sine gated amplifiers.

The function of the sine-cosine resolver is to resolve track angle error into its sine and cosine components.

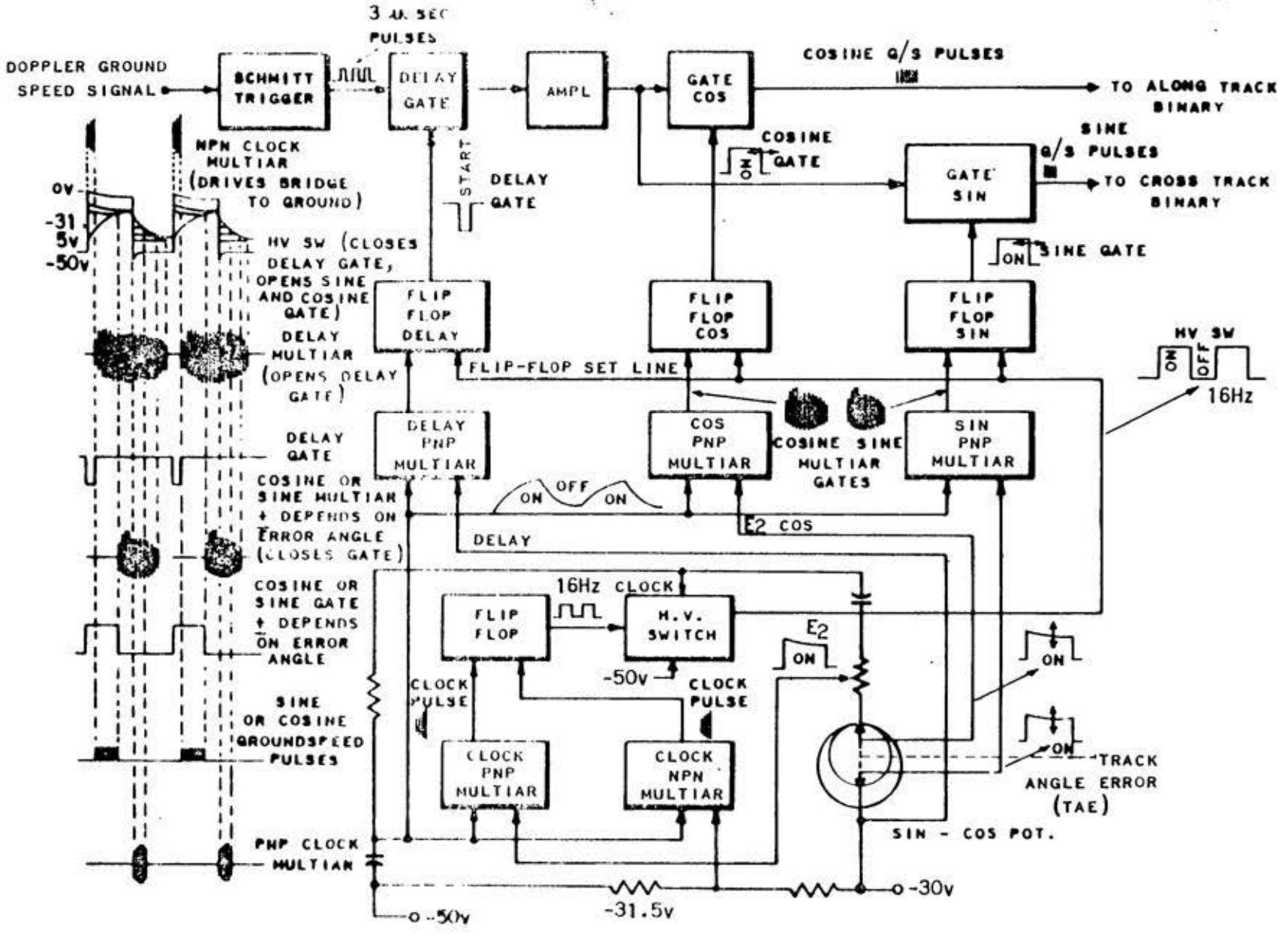
Each clock on time enables the start of the sine and cosine gates. As E-1 decreases toward 0 volts, it will reach a variable amplitude portion of E2, which is picked off by the sine arm of the sine-cosine potentiometer whose



SIMPLIFIED CLOCK CIRCUIT



GATE GENERATOR WAVEFORMS



GATE GENERATOR BLOCK DIAGRAM

shaft is positioned by the track angle error servo. The coincidence of E1 and E2 fires the sine multiar which triggers the sine flip-flop ending the sine gate. The voltage E1 decreases further, meeting another variable amplitude portion of E2 picked off by the cosine arm. The cosine multiar oscillates at the coincidence of E1 and E2 triggering the cosine flip-flop ending the cosine gate. A still further decrease of E1 permits the clock multiar to oscillate, triggering the clock flip-flop ending the clock on time.

The number of ground speed pulses that pass to the binary counters is controlled by the time length of the sine and cosine gates. At 20.66 Hz from the radar with a ground speed of one nautical mile per hour (knot) there are 74,376 ground speed pulses from the pulse shaping circuits. Since the maximum on time of the cosine and sine gated amplifiers is less than clock on (50 percent of time) only 40.33 percent (30,000) of the pulses are passed to the binary dividers.

When the Doppler radar set control is in "SEA" mode the Doppler ground speed signal is 20.48 Hz/knot. Radar "SEA" mode activates a sea mode relay in the computer changing the clock reference voltage from minus 50 to minus 50.9 volts, DC, increasing the sine and cosine gate lengths allowing more pulses to pass to the binaries, thus compensating for lower ground speed signal. All other radar mode switching will change the binary counting.

DETAILED ANALYSIS OF DISTANCE COUNTING

The 30,000 pulses per mile traveled along track must be reduced (divided) to one (1) pulse per mile (computer "NAV" mode) to actuate the DISTANCE-TO-GO solenoid indicator. The along track binaries divide by 30,000. The cross-track binaries divide by 3,000 providing 10 pulses per cross track mile traveled actuating the cross track solenoid. In computer "DROP" mode the along track binaries, dividing by 3,000, produce 10 pulses per mile traveled while the cross-track binaries, dividing by 300, produce 100 pulses for each crosstrack mile traveled.

In radar "Smooth Sea" mode the binary division is changed as follows:

10,000	-	along track	- computer "NAV" mode
1,000	-	cross track	- computer "NAV" mode
1,000	-	along track	- computer "DROP" mode
100	-	cross track	- computer "DROP" mode

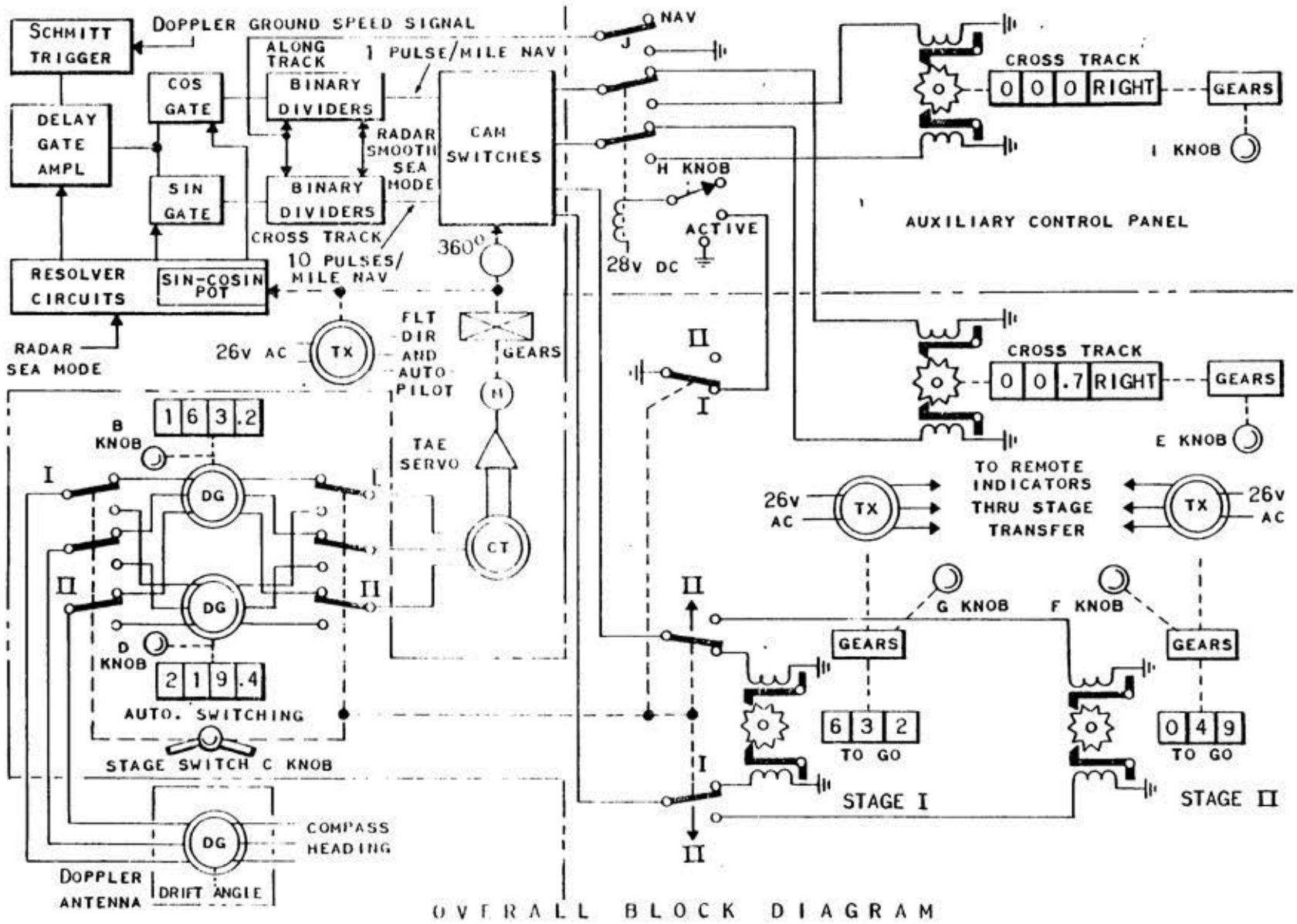
This change in division compensates for the low ground speed signal produced by the radar in Smooth Sea. The control panel indicators remain normal as determined by the computer "NAV-DROP" mode.

The changes in binary division are accomplished by relays. The relays are controlled by Smooth Sea or not Smooth Sea radar modes and by "NAV-DROP" computer modes. The relay contacts alter binary divider feedback circuits changing the binary division.

Since the sine and cosine functions repeat in TAE changes up to 360 degrees, it is necessary for TAE to position cam operated switches to select the proper indicator solenoids. As mentioned earlier, there are four combinations of solenoid selections.

TAE	Distance-to-go Solenoid	Crosstrack Solenoid
0 to 90 degrees	Decrease	RIGHT
90 to 180 degrees	Increase	RIGHT
180 to 270 degrees	Increase	LEFT
270 to 360 degrees	Decrease	LEFT

It can be seen from the overall block diagram that TAE is fed by a synchro transmitter to the autopilot and flight director system. The distance to go is also transmitted to the flight director. The cross track gear boxes in both control panels mechanically drive potentiometers providing the flight director with plus or minus D-C deviation voltage and the autopilot with reversable phase, A-C deviation voltage.



OVERALL BLOCK DIAGRAM