CARNEGIE-MELLON UNIVERSITY

HYBRID COMPUTATION LABORATORY

GPS

Operating Manual for the GPS Analog Computer

September, 1968

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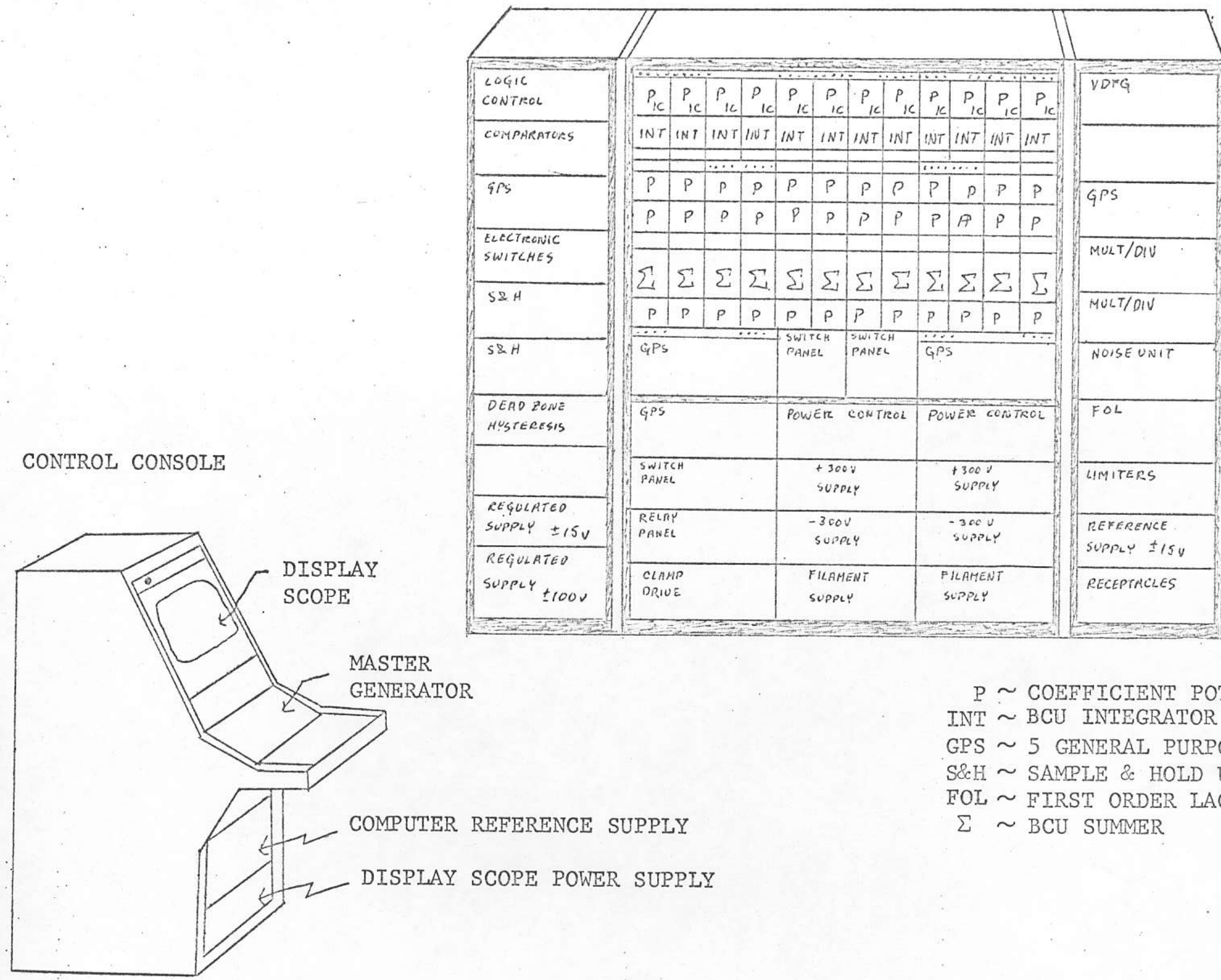
GPS ANALOG COMPUTER

1.0 MACHINE ORGANIZATION

An overall view of the GPS analog computer is given in Figure 1.1. The component complement is as follows:

BCU INTEGRATORS	~	12
BCU SUMMERS	~	12
COEFFICIENT POTS	~	48 (MAX)
VDFG	~	2 (5 SEGMENT)
GENERAL PURPOSE SUMMERS	~	20
MULTIPLIERS/DIVIDERS	~	2
LIMITERS	~	2
DEAD ZONE/HYSTERESIS	~	2
FIRST ORDER LAG	~	4
SAMPLE & HOLD	~	8
LOGIC CONTROL UNIT	~	1
COMPARATORS	~	6
ELECTRONIC SWITCHES	~	6
RELAY SWITCHES	~	8
NOISE UNIT	~	1

The problem solution is controlled from the control console which contains the display scope, the master generator, and the ± 50V REF. supply.



P ~ COEFFICIENT POT
INT ~ BCU INTEGRATOR
GPS ~ 5 GENERAL PURPOSE SUMMERS
S&H ~ SAMPLE & HOLD UNIT
FOL ~ FIRST ORDER LAG UNIT
Σ ~ BCU SUMMER

FIGURE 1.1

The individual components are housed in slide out trays; each tray contains one type of computing element. The comparator tray, for example, contains six comparators. Each Sample & Hold tray contains four Sample & Hold units. In the upper left hand corner of each tray there is a name-plate which identifies the type of computing components to be found in that tray and a number to distinguish between trays containing the same type of components. Each unit within a tray is identified by a letter. Thus each computing component has a unique identification.

As illustrated in Figure 1.1, the GPS Analog Computer contains two basic Computing Units (BCU) each of which contains six BCU integrators, six BCU summers and a maximum of 24 coefficient pots. The pots are laid out in 4 rows each containing 6 pots, and are labeled 1 through 24. The first 6 pots, which are located directly above the BCU integrators, serve a dual purpose. They can serve as regular coefficient pots or can be used to set the initial condition on the integrator directly below.

To facilitate patching each BCU contains 30 horizontal trunk lines labeled L1 through L30. These trunk lines terminate along the sides of the BCU unit. There are 12 vertical trunk lines labeled J1 through J12 which terminate just below the -OUT of the integrators and just above the OUT of the summers. There are two trunk lines ML1 & ML2 which terminate on both BCU switch panels and on the master generator. These trunks facilitate patching to the display scope. The BCU switch panels also contain jacks supplying the ±50V.REF supply voltage.

An amplifier is regarded as being overloaded when its output voltage exceeds 55 volts. An overload indication is provided for each BCU integrator and each BCU summer. These overload indicators are located at the top of the BCU tray. All other amplifiers have their O.L. indicators mounted on their respective trays. Some components contain more than one O.L. indicator, because they contain more than one amplifier. Each amplifier in the unit is provided with an O.L. indicator. A component having multiple overload indicators is regarded as being overloaded when at least one O.L. indicator is lit.

1.1 START UP PROCEDURE*

1) Turn on the individual power switches for each regulated supply, the reference supplies and the oscilloscope power supply.

2) Power is supplied to all filaments and power supplies by depressing the FILAMENT START button on the power control trays.

3) On each power control unit there is a ready light. Plate power cannot be applied until the ready light is on. When starting the computer for the first time in the day there should be a warm-up period of 30 minutes. Make sure the intensity control on the display scope is turned all the way down (CCW) during this warm up period.

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*Ch2 & 3 should be read before reading the start up procedure.

4) Depress the PLATE START buttons on the power control trays.

5) Each component has its own plate power switch located on its respective tray. The components to be used may now be activated.

6) Adjust the power supplies for the correct output voltage starting with the power control supplies. (REFER TO FIGURE 1.1 FOR THE LOCATION OF THE POWER SUPPLIES). Using the screw driver adjustment, set the supplies on the power control tray to +100 VOLTS. Set the voltage on the 300V supplies directly below the power control tray to +300 VOLTS. Use the appropriate screwdriver adjust pots. Patch the outputs of the regulated supplies ($\pm$ 15V reference, $\pm$ 15V regulated, $\pm$ 100V regulated) to INI-DIR for scope display. Using the calibrator line as a reference, set these supplies to the correct voltage.

GPS ANALOG COMPUTER

2.0 DISPLAY SCOPE

The display scope is a single channel 17" cathode ray oscilloscope. It is used as an X-Y plotter for plotting one problem variable against another or for plotting one problem variable vs a calibrated time sweep from the master generator.

2.1 FUNCTION OF CONTROLS

VERTICAL AXIS	VOLTS/IN	Step attenuator providing an OFF position and sensitivities of 10,1,.1,.01 VOLTS/IN with the yoke switch in series and 20,2,.2,.02 VOLTS/IN with the yoke switch in parallel.
	MULTIPLIER	Calibrated potentiometer providing a 10 to 1 attenuation of the step attenuator setting
	VERTICAL POSITION	Adjusts the vertical position of the trace.
	DC INPUT	This jack provides a direct connection to the vertical attenuator.
	YOKE SWITCH	This switch is located just above the deflection yoke. In the series connection the vertical sensitivity is that selected on the attenuator. In the parallel position the sensitivities are decreased by a factor of two.

HORIZONTAL AXIS	VOLTS/IN	Step attenuator which provides a sweep position, an off position, and sensitivities of 10,1,.1,.01 V/IN.
	MULTIPLIER	Calibrated potentiometer providing a 10 to 1 attenuation of the step attenuator setting.
	HORIZONTAL POSITION	Adjusts the horizontal position of the trace.
	DC INPUT	Provides a direct connection to the horizontal input attenuator.
Z AXIS	INTENSITY	controls the trace intensity.
	FOCUS	focuses the trace
	Z AXIS	provides a connection to the grid of the CRT for Z axis modulation.
	SWEEP	The internal sweep is not used. Select OFF on the MS/IN switch.

2.2 OPERATOR MAINTAINENCE

Before using the scope the operator should balance the horizontal and vertical amplifiers as follows: Select OFF on both the vertical and horizontal scale selector switches. Set the DC BAL. (Screw-driver adjust on front panel) so that no spot shift occurs as the vertical and horizontal multiplier controls are rotated.

3.0 MASTER GENERATOR

The master generator is the control center for the GPS computer. It supplies all the synchronizing signals necessary for operation as listed:

1) The MG determines the solution repetition rate (REP. RATE)

2) The time duration of the problem

3) The generation of a step or pulse forcing function

4) The sweep voltage for the display scope X axis

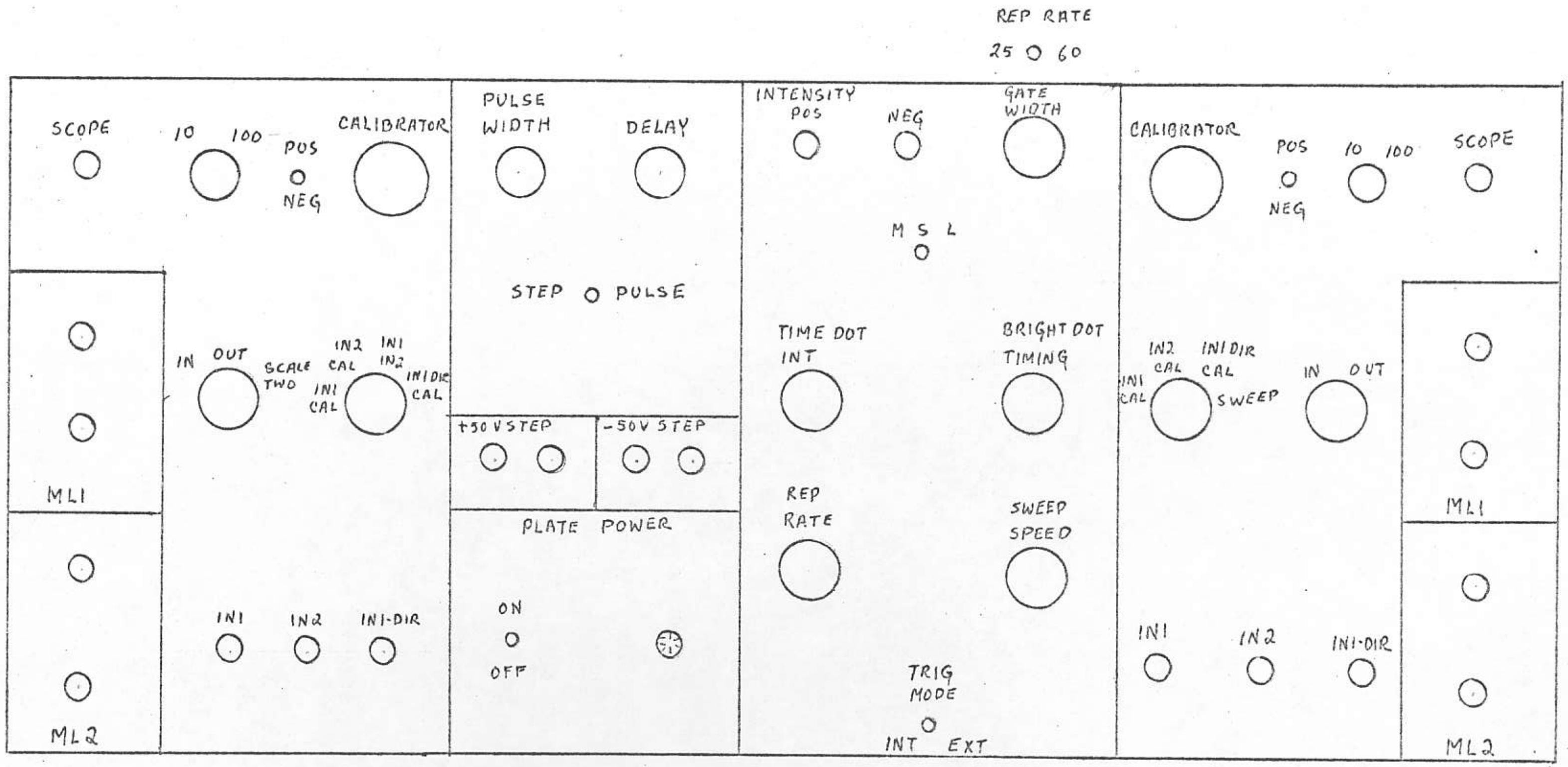
5) The time dots & intensity signal for the scope Z axis

6) Provides clamped inputs for signals which are displayed on both the X and Y axes.

7) The calibrated voltage for amplitude measurements on both axes.

3.1 FUNCTION OF CONTROLS

REP RATE — This control determines the number of solutions per second. The rate is continuously variable from 15/SEC (CCW) to 60/SEC (CW). For synchronized operation the repetition frequency must be a submultiple of 120. This control is adjusted for no horizontal "jitter" of the scope display at the approximate rep. rate desired. The optimum setting is the center between the maximum and minimum lock in settings for any particular rep. rate.



MASTER GENERATOR

GATE WIDTH — Determines the problem display time (the length of the operate time). This control is adjustable from 18 to 150 T.U. (time units). A T.U. is 1/3014 seconds. The gate width is related to the rep. rate by

$$\text{GATE WIDTH} + \text{OFF TIME} = \frac{1}{\text{REP. RATE}}$$

The off time should be at least 20 msec.

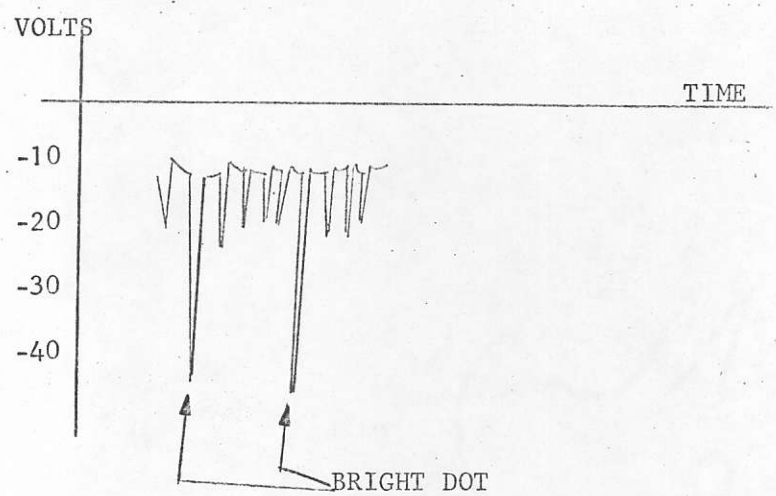
PULSE WIDTH — Determines the time duration of the step or pulse as selected by the function selector switch (CCW minimum, CW maximum). When using a step forcing function adjust the step width to be as long as the gate width.

TIME DELAY — Delays the start of the step or pulse with respect to the start of the gate; it "allows time for everything to get started". This control is usually adjusted for the step to start at the 4th timing dot which then becomes t=o.

TIME DOT INTENSITY — This control adjusts the brightness of the timing dots relative to the brightness of the trace.

BRIGHT DOT TIMING

Determines the time interval between the bright timing dots. This control is usually adjusted for a bright dot every 5th time dot over the entire gate width. Other intervals from 2 to 7 can be adjusted. Adjustment can be facilitated by patching the NEG. INTENSITY into the IN1-DIR of the master generator. Adjust the controls for a display and observe that the repetition rate of the bright dot is correct.



SWEEP SPEED

Determines the slope of the sweep voltage. (The sweep voltage is a ramp). The function of this control is similar to that of the horizontal gain control. To prevent X-Y cross coupling, the scope gain should be set to the minimum possible value, especially the multiplier control, and adjustment of the sweep display should be made with the sweep speed control.

TRIG MODE	Determines the source of the timing signals either internal or external. The external position is used when two GPS computers are interconnected. The trigger mode should be kept in the internal position.
MAX VOLTS	Determines the scale factor for the calibrator voltage setting.
CALIBRATOR	Adjustable 10 turn potentiometer used to select the desired calibrated voltage output. Voltages are adjustable from 0-10 VDC & 0-100 VDC.
INPUT SELECTOR	Connects the IN1, IN2 & IN1-DIR jacks through coupling & MSR circuits to the SCOPE output jack. The horizontal selector has a SWEEP position to provide a time base.

POSITION

IN1-CAL Patches the signal on the IN1 jack to the SCOPE output jack through a clamp circuit. The calibrator line on the horizontal axis is displayed alternately if the IN OUT switch is IN. The vertical calibrator line is displayed alternately with the input when the IN OUT SCALE TWO switch is IN and the IN OUT switch is OUT.

IN2-CAL This position selects the input on jack IN2 for display. The calibrator line can be made to alternate with the solution in the same way as for jack IN1.

IN1-IN2 Alternately displays the clamped signals on IN1 and IN2 if the IN OUT SCALE TWO is IN and the IN OUT switch is OUT.

IN1-DIR CAL Patches the input on the IN1-DIR jack to the SCOPE output jack. This position is used to zero balance the computer amplifiers. The calibrate line can also be made to alternate with the input signal.

IN OUT

SCALE TWO

The IN & OUT positions determine how the calibrator line alternates with the problem solution. SCALE TWO determines whether the forcing function (the ±50V step from the MG or ± 50V regulated reference) is applied during each operate time or during alternate operate times. This permits a comparison of the problem solution with and without excitation. The SCALE TWO position is usually used to observe the noise level in the problem and to check on integrator reset.

PLATE POWER ON/OFF	Applies plate power to the M.G.
FUNCTION SELECTOR STEP/PULSE	Selects a step or pulse forcing function.
CAL. LINE POS/OFF/NEG	Determines whether the calibrate line will be positive, negative or off.
MSL	Coarse selector for the sweep speed. Position L is the longest, in position M the sweep speed is approximately twice the speed of position L and position S is approximately twice as fast as position M.
REP RATE 25/60	Determines the maximum repetition rate for the solution that can be selected from the rep rate pot. With the switch in the 25 position the rep rate can be varied from 15 to 25 rps. In the 60 position the rep rate can be varied from 30 to 60 rps.
JACKS	
$\pm$ 50V STEP	These jacks provide $\pm$50V step or pulse as selected by the function selector switch. This output should be connected to a pot for amplitude control since the output voltage is not regulated.
INTENSITY POS	Provides Z axis modulation for the display scope.
SCOPE (RIGHT SIDE)	X axis output from the M.G. This jack should be patched to the DC horizontal input on the display scope.
SCOPE (LEFT SIDE)	Y axis output from the M.G. This jack should be patched to the DC vertical input on the display scope.

IN1, IN2	Inputs jacks for signals to be displayed.
IN1-DIR	Direct coupled input. This input is used to balance the amplifiers.
ML1, ML2	Trunk lines from the BCU switch panels.

3.2 OPERATING PROCEDURE

The MG should be patched to the display scope by patching the left SCOPE jack to the vertical amplifier DC input, the right scope jack to the horizontal amplifier DC input and the POS INTENSITY to the scope Z AXIS.

A scope display can be obtained by setting the controls as follows:

CONTROL	INITIAL SETTING
REP RATE	CCW (minimum)
GATE WIDTH	CW (maximum)
SWEEP SPEED	CENTERED
TIME DOT ITENSITY	CW (maximum)
IN OUT	OUT
IN OUT SCALE TWO	OUT
HORIZONTAL INPUT SELECTOR	SWEEP CAL

Adjust the display scope controls to obtain a sweep across the entire screen. Once the sweep is obtained, the MG can be adjusted.

1) Adjust the SWEEP SPEED and the display scope horizontal amplifier as explained in the function of controls section (Section 3.1)
2) Adjust the REP RATE for a synchronized display at the lowest possible rep rate (CCW). Synchronization is characterized by no horizontal jitter.
3) Adjust TIME DOT INTENSITY for easy viewing.
4) Adjust the BRIGHT DOT TIMING for the desired repetition rate over the entire gate width.

5) Patch the MG STEP into IN1-DIR and display the waveform on the scope. Adjust the TIME DELAY so that the step starts on the third or fourth timing dot.

6) Adjust the gate width for the desired display time.

7) Adjust the sweep speed for the desired sweep display.

8) If the MG step forcing function is to be used, adjust the PULSE WIDTH so that the step is as wide as the gate.

9) Adjust the REP RATE for the desired value.

10) Patch the signals to be displayed into the appropriate jacks.

4.0 BCU INTEGRATOR

The BCU integrators are located on the BCU trays just below the first row of pots. A typical integrator patchboard layout is shown in FIGURE 4.2 together with associated I.C. pot and a simplified schematic is presented in FIGURE 4.1.

Each BCU integrator has a fixed RC of 3014.

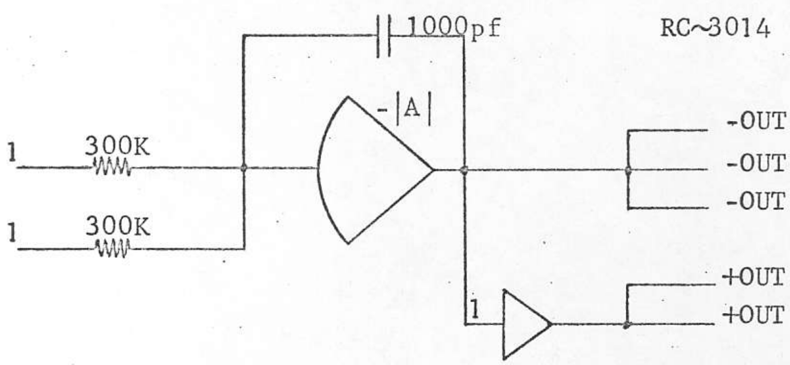
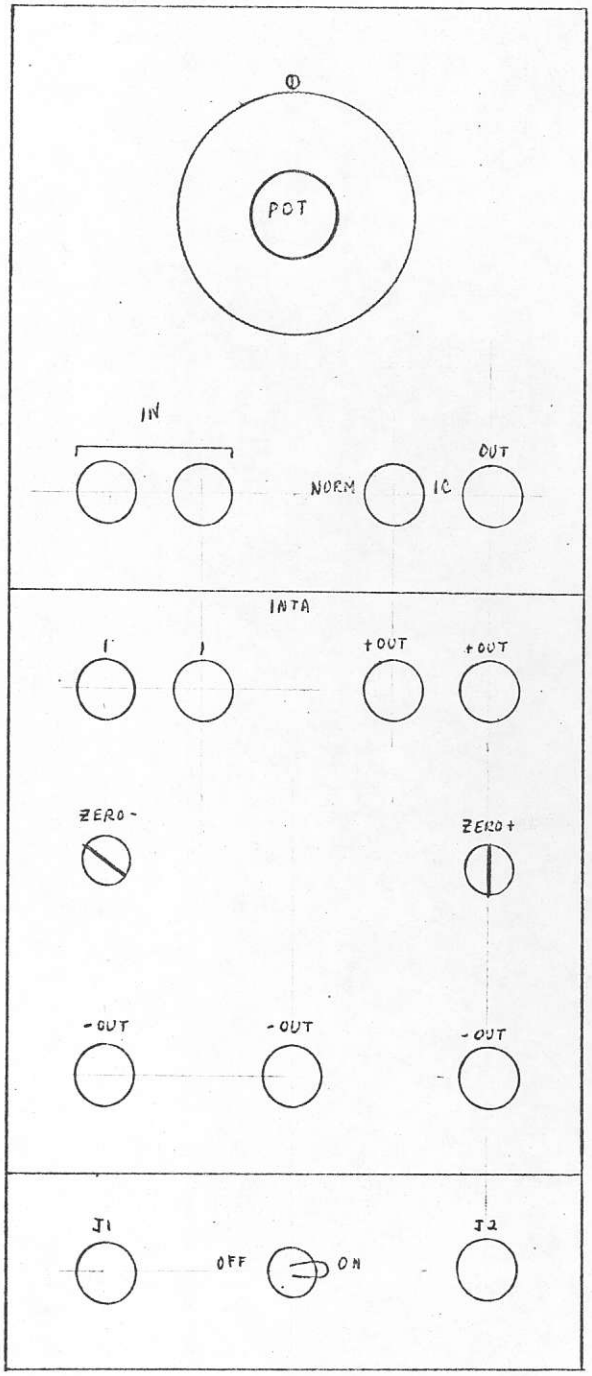


FIGURE 4.1 GPS INTEGRATOR SCHEMATIC

Before using the BCU integrator the operator must zero balance the integrators as follows: Patch the integrator -OUT to the IN1-DIR input jack on the MG. (vertical input). Set the display scope sensitivity to .1V/IN. Adjust the -ZERO pot for zero volts output. Repeat this adjustment for the +ZERO pot using the +OUT jack. The integrator is now ready for operation.



GPS INTEGRATOR PATCHBOARD LAYOUT

FIGURE 4.2

4.1 SETTING AN INITIAL CONDITION

Although the reference voltage for the computer is 50 volts, the maximum value of the initial condition is 6 volts. If the initial condition is zero, no external patching is required. For a non-zero initial condition, the following procedure may be used. Select IC on the NORM/IC switch above the integrator. Patch the $\pm$ 50 V STEP from the MG into the IN jack of the I.C. potentiometer. Patch a red grounding plug into either integrator input jack. Monitor the integrator output on IN1-DIR. Twiddle the I.C. pot until the desired IC is set. The integrator is reset to zero value during the computer "off" time. The initial condition is established again at the beginning of the next solution.

5.0 BCU SUMMERS

The BCU summers are located on the BCU trays just below the third row of pots. The patchboard layout of a typical summer is shown pictorially in Figure 5.1 and a simplified schematic is shown in FIGURE 5.2.

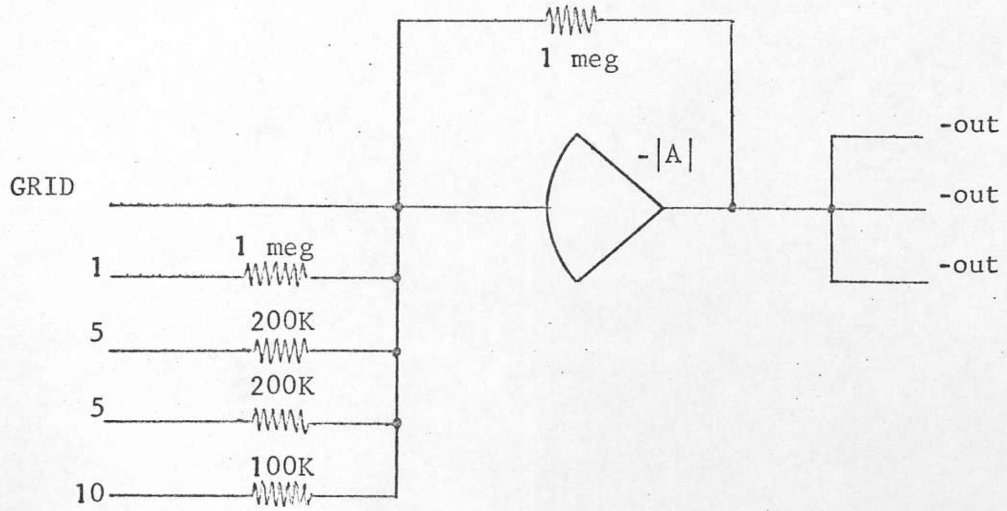
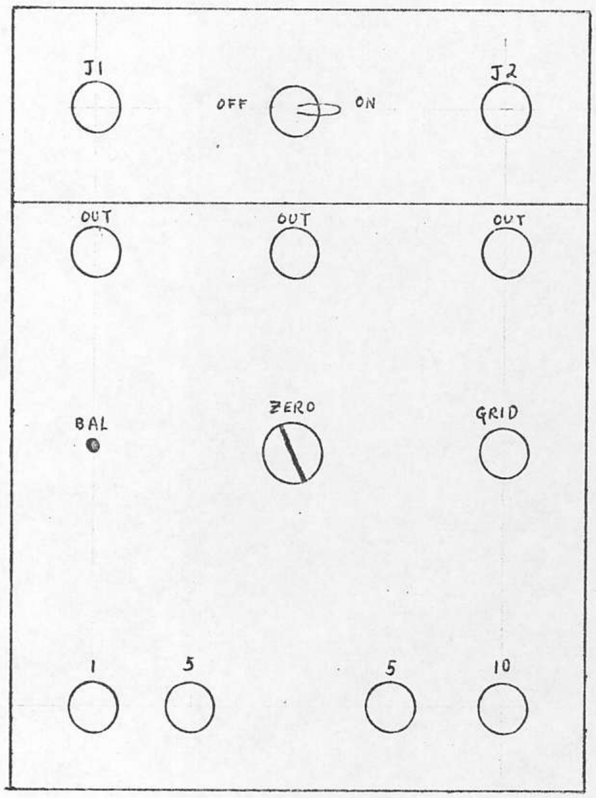


Fig. 5.2 GPS Summer Schematic

The operator checks the summer for operation by depressing the BAL button and observing that the O.L. indicator lights and extinguishes when the button is released. The summer can be zeroed by removing all inputs and patching the OUT jack to IN1-DIR. The ZERO pot should be adjusted for zero volts output on the .1V/IN scale.



GPS SUMMER PATCHBOARD LAYOUT

FIGURE 5.1

6.0 COEFFICIENT POTENTIOMETER

Each BCU contains 24 coefficient potentiometers the first six having the dual capability of operating in the normal mode or setting the IC on the integrator directly below. Each pot has the configuration of Figure 6.1.

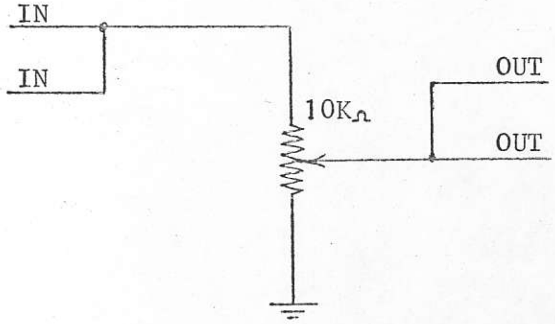


Figure 6.1 GPS Potentiometer Schematic

NOTE: The first 6 pots only have 1 out jack.

All potentiometers are calibrated for a 100KΩ load, the input impedance of the operational amplifiers. The accuracy is ±.5% for a visual setting. Higher accuracy can be obtained by using the calibrator line of the display scope as a reference.

7.0 GENERAL PURPOSE SUMMERS

The GPS has 5 trays of general purpose summers, 4 in each tray. The schematic is shown in Fig. 7.1. These summers should be balanced using the procedure used for the BCU summers.

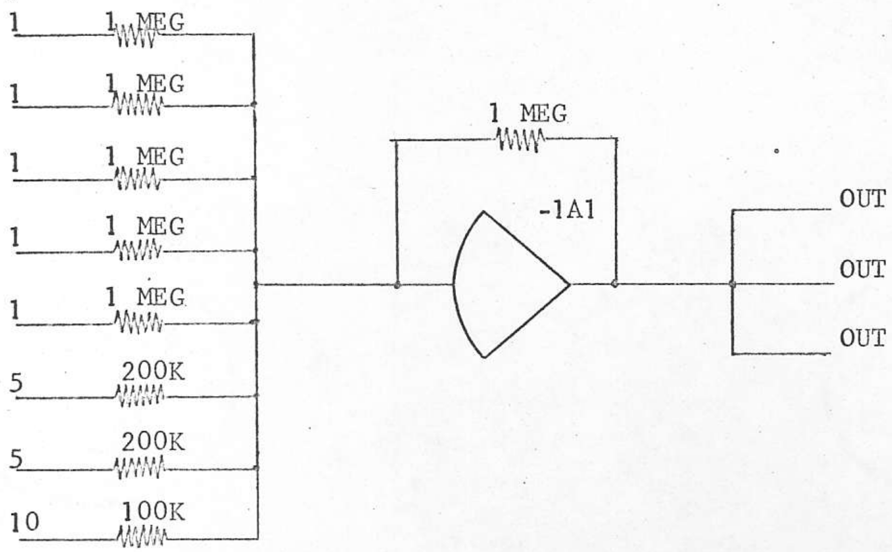


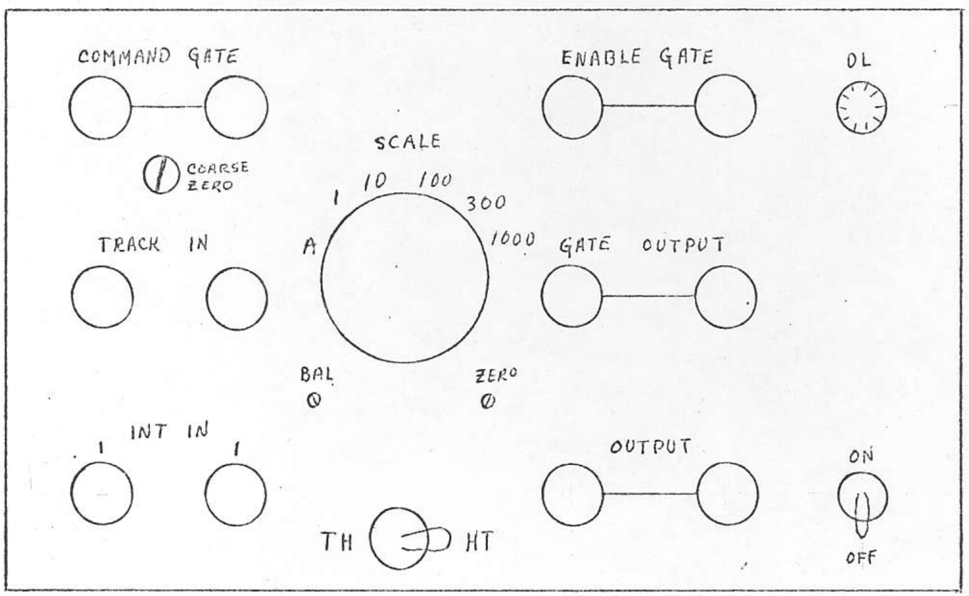
Fig. 7.1 General Purpose Summer Schematic

8.0 SAMPLE AND HOLD

A typical Sample and Hold patchboard layout is shown in Fig. 8.1. The GPS computer has 8 such units each having the following operational capabilities.

1. Track the value of a variable input voltage on command and hold the instantaneous value of the signal being tracked when the command is removed. The held value is presented as a constant output voltage. On the next command the Sample and Hold will again track the input signal. The held value may be read out continuously or on command.

2. The Sample and Hold may be used as an integrator with any one of 5 sensitivities. The Sample and Hold can be commanded to reset or it can integrate continuously until its amplifier overloads.



GPS SAMPLE AND HOLD PATCHBOARD LAYOUT

FIGURE 8.1

3. The Sample and Hold can be used as a double pole, single throw electronic switch.

8.1 PANEL CONTROLS

ON/OFF — Applies plate and bias potentials.

TH/HT — Mode selector switch. When used as a Sample and Hold, the TH position allows the unit to track and hold on command, HT selects hold and track on command. When the Sample and Hold is to be used as an integrator select the HT mode. The TH position is used to manually reset the integrator.

SCALE SELECTOR — Position A is selected to use the device as an electronic double pole single throw switch. When used as an integrator, positions 1 to 1000 select the integrator sensitivity. When used as a sample and hold, positions 1 to 1000 indicate the tracking speed and the holding ability of the circuit.

POSITION	SWITCHING SPEED (-50V to +50V)	DECAY
1	25 msec	100µv/sec
10	25 msec	1 mv/sec
100	250 µsec	10 mv/sec
300	75 µsec	30 mv/sec
1000	25 µsec	100 mv/sec

COMMAND GATE — The command gate has two functions depending on the mode of operation. When used as a Sample and Hold a high input (12-15 volts) causes the unit to track when the TH/HT switch is in the HT position and to hold when in the TH position. When used as an integrator a high input signal causes the integrator to reset to its initial condition.

ENABLE GATE — Logic input which presents the output voltage at the gate output when the enable gate is high and zero output when the enable gate is low.

TRACK IN — The signal to be sampled and held is patched into the TRACK IN. The two TRACK IN inputs will sum at minus unity gain. When used as an integrator the IC is patched into the TRACK IN and is minus the sum of the two TRACK IN voltages.

INT IN — Input for the device when used as an integrator. The two inputs sum at minus unity gain. With the TH/HT switch in the HT position a signal is required at the command gate input to reset the integrator to its track in value. In the TH position the integrate and reset timing are reversed. This jack also serves as a signal input when used as an electronic switch.

GATE OUTPUT — The output voltage appears at the gate output whenever the enable gate is high.

OUTPUT — Continuous output for any mode of operation.

8.2 OPERATING PROCEDURE

The sample and hold should be zero balanced for proper operation.

1. Turn the TH/HT mode selector switch to the TH position.
2. Turn on the plate power and allow 30 minutes warm-up.
3. Set the selector switch to 100.
4. Remove all inputs.
5. Patch the OUTPUT to IN1-DIR for scope display.
6. Set the toggle switch to the HT position and adjust BAL for minimum drift.
7. Set the toggle switch to the TH position and adjust the fine zero for zero volts output.

SAMPLE AND HOLD

To use as a sample and hold, patch the input signals to the TRACK IN. Patch the logic signal into the COMMAND GATE. Set the TH/HT to the desired position and the scale selector to the desired sensitivity. The output is taken from either the GATE OUTPUT or the OUTPUT.

INTEGRATOR

Set the TH/HT switch to HT. Patch the input signal to INT IN and the initial condition to TRACK IN (if other than zero). Set the scale selector to the desired integrator sensitivity. If the integrator is to reset on command, patch the logic command signal into the command gate. The output is taken from either the OUTPUT or the GATE OUTPUT. Unlike the BCU integrators, the IC can be set to any voltage between ± 50 volts.

ELECTRONIC SWITCH

Set the scale selector to position A and TH/HT switch to HT. Patch the N.O. input to TRACK IN and the N.C. input to INT IN. Patch the switch coil (logic input) into the COMMAND GATE. The output is taken from the OUTPUT jack. The N.O. & N.C. contacts can be reversed by selecting the TH position.

GPS ANALOG COMPUTER

9.0 ELECTRONIC MULTIPLIERS

The GPS has two QSM multipliers which by appropriate patching can be set up to divide. A multiplier patchboard layout is given in FIG. 9.1

9.1 PANEL CONTROLS

SELECTOR SWITCH The selector switch selects the signal output present on the SELECTOR OUTPUT jacks. Positions f_1, f_2, f_1 DIR, & f_2 DIR select the signal patched into the corresponding input jacks. Positions 1, 2, 3 & 4 are for balancing the amplifiers.

MULT/DIV Selects the mode of operation. The unit can be used to multiply or divide.

+2xy/-2xy Selects the input output relationship. In the +2xy position the output signal is plus 2xy where x & y are the inputs signals patched into f_1 & f_2; -2xy selects minus 2xy where x & y are the input signals. The input signals are normally patched into f_1 & f_2.

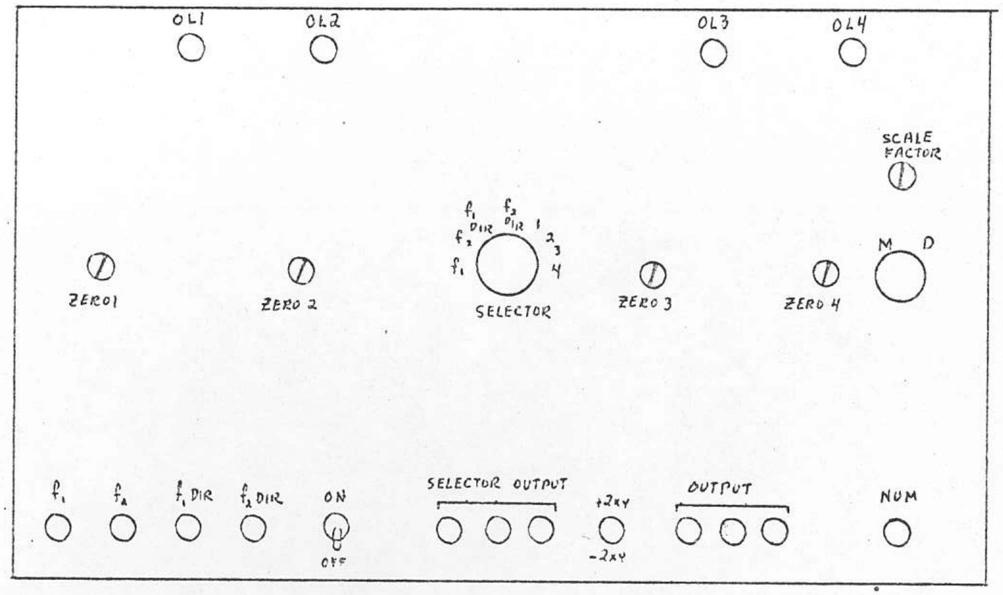
f_1 DIR, f_2 DIR These input jacks are used for calibration and the divider set-up procedure.

SELECTOR OUTPUT The selector jacks provide a signal output determined by the selector switch.

OUTPUT The product $\pm 2xy$ is presented at the output jacks.

NUM When set up to divide, the numerator input is patched into the NUM jack.

The multiplier can be zero balanced by using the following procedure:



GPS MULTIPLIER PATCHBOARD LAYOUT

FIGURE 9.1

1) Remove all inputs

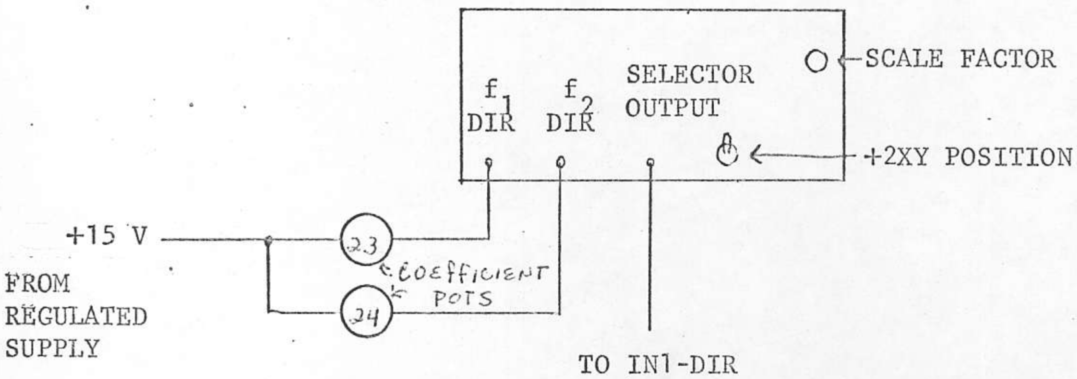
2) Check and adjust if necessary the $\pm$ 15 volt reference supply. Use the method outline in the start-up procedure.

3) Patch the selector output to IN1-DIR on the MG for scope display

4) Select position 1 and adjust ZERO 1 for zero volts output

5) Repeat this procedure for positions 2, 3, & 4

6) Patch the circuit shown below



7) Select f_1 DIR on the selector switch. Using the calibrator line as a reference, carefully adjust pot 23 for +5 volts. Repeat this procedure by selecting f_2 DIR and adjusting pot 24.

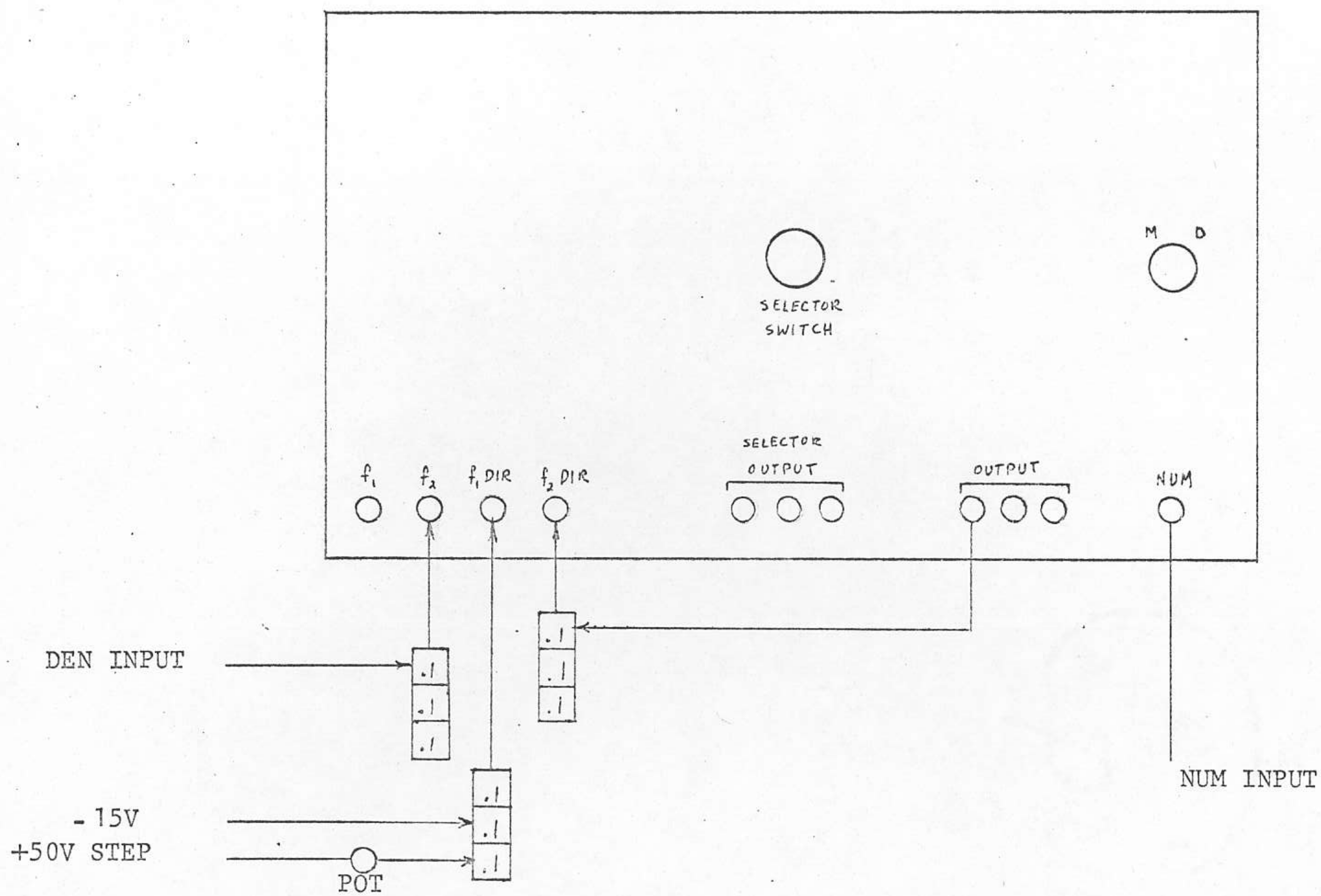
8) Select position 4. The selector output voltage should be 50 volts. Using the calibrator line as a reference, set the scale factor pot so that this voltage is +50 volts.

9.2 OPERATING PROCEDURE

MULTIPLIER OPERATING PROCEDURE Patch the signals to be multiplied into f_1 & f_2. Set the MULT/DIV switch to MULT. The output voltage is $\pm 2f_1f_2$ depending on the position of the 2xy/-2xy toggle switch. Note that the input voltages should be scaled for a maximum value of 5 volts so that the multiplier will not overload. Since the input impedance of the multipliers is constant it is not necessary to drive them with operational amplifiers.

DIVIDER OPERATING PROCEDURE (REFER TO FIG 9.2)

1) Remove all inputs. Zero the four amplifiers using the same



DIVIDER SET-UP PROCEDURE

FIGURE 9.2

procedure as for the multiplier.

2) Patch -15 V. DC from the regulated supply through a .1 attenuator to f_1 DIR.

3) Patch +50 V. REF through a pot to the above attenuator.

4) Select position 1 on the selector and +2xy on the toggle switch.

5) Patch the selector output to the IN1-DIR for a display.

6) Adjust the step input pot for zero volts out.

7) Apply the feedback connection from the output through a .1 attenuator into f_2 DIR.

8) Select DIV on the MULT/DIV switch.

9) Select position 4 on the SELECTOR switch and adjust zero 4 for zero volts out.

10) Patch the denominator input through a .1 attenuator into the f_1 input.

11) Patch the numerator into NUM.

The scale factor for the above procedure is 50. The output voltage is $\frac{50\ NUM}{DEN}$. The range of the input voltages are

DEN ~ -50 V to 0 NUM ~ -50 to +50 QUOTIENT is ~ -50 to +50 volts

The scale factor can be changed to 5 by patching the numerator input through a .1 attenuator. By removing the attenuator in the denominator input the scale factor can be reduced to .5. Note that the denominator input must be negative. Positive denominators can be used if -2xy is selected on the +2xy / -2xy toggle switch.

10.0 LIMITER

The GPS has two variable limiters. The input-output performance is a negative gain adjustable symmetrical limit or a separately adjustable positive and/or negative limit. The limiter patchboard layout is shown in FIG 10.1.

PANEL CONTROLS

-LIM Adjusts the negative limit

+LIM Adjusts the positive limit

±SYM LIM Adjusts the symmetrical limit

INPUTS For normal operation, the clamped inputs should be used. The input voltages sum at minus unity gain. The direct inputs may be used if there is no D.C. drift on the input signal.

OUTPUT The output for the +LIM -LIM & ± SYM LIM are taken from their respective jacks.

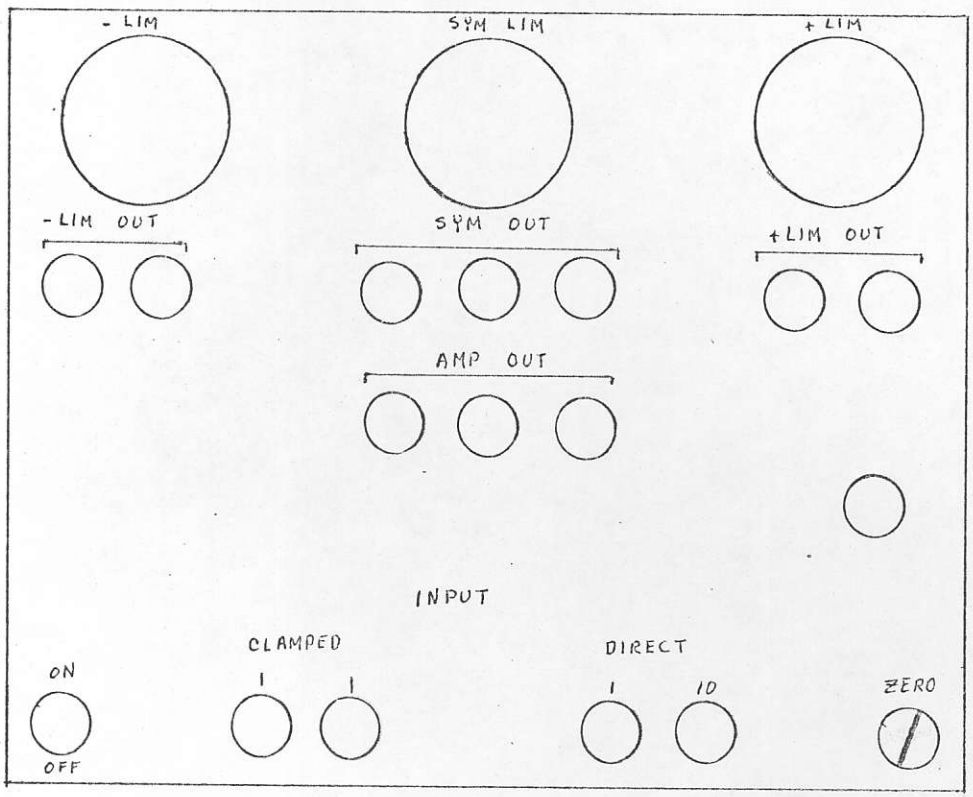
The amplifier output (AMP OUT) jacks provide an output voltage which is equal to the sum of the inputs with a minus unity gain.

10.1 SETTING THE LIMIT LEVELS

Zero adjust the amplifier using the same procedure as was used for the general purpose summers. Apply a ramp input with a large enough initial condition so that the desired limit levels are exceeded. Patch the appropriate limit output to the scope using IN1-DIR. Use the calibrator line as a reference when setting the limits.

+LIM OR -LIM Set ±SYM LIM pot (CCW). Adjust the appropriate lim pot for the desired output.

±SYM LIM Set the +LIM & -LIM (CCW). Adjust the SYM LIM pot for the desired output.



GPS LIMITER PATCHBOARD LAYOUT

FIGURE 10.1

+LIM & -LIM Both limits can be set independently by setting the SYM LIM CCW, and by adjusting the +LIM & -LIM for the desired limit values. The output is taken from the ±LIM OUT.

All limits are adjustable from 0 to ±50 volts.

GPS ANALOG COMPUTER

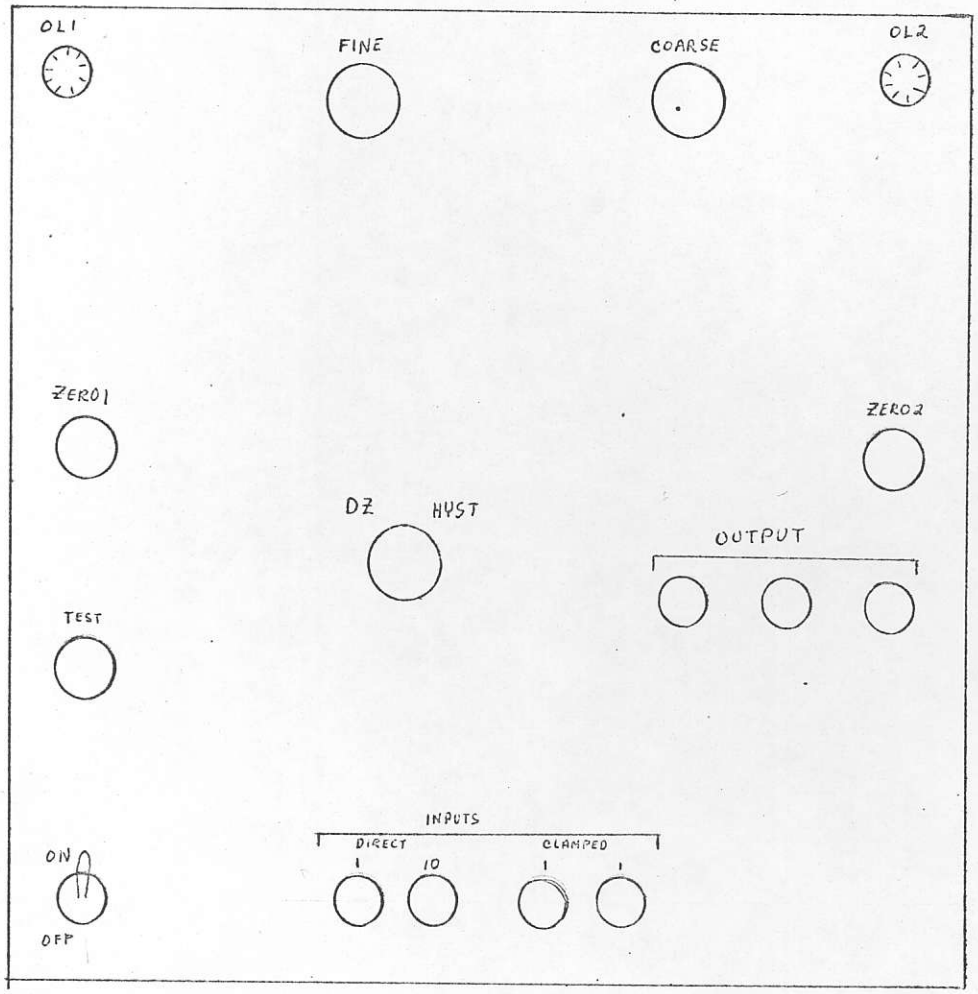
11.0 DEAD ZONE - HYSTERESIS

The GPS has two dead zone-hysteresis units (FIG 11.1). The input-output performance is either a negative gain symmetrical dead zone or hysteresis loop as selected by the D.Z. - HYST. mode switch.

11.1 OPERATING PROCEDURE: Remove all inputs. Select DZ on the mode control switch. Patch the test jack to IN1-DIR for scope display. Adjust ZERO 1 for zero volts out. Patch the output jack to IN1-DIR. Adjust ZERO 2 for zero volts out.

DEAD ZONE ADJUSTMENT Construct a simple sinusoidal oscillator using two integrators and a few pots. Patch the output of the oscillator to the clamped input and to the IN1-DIR (HORIZONTAL) jack. Patch the output to IN1-DIR (VERTICAL). Adjust the coarse & fine pots for the desired DZ output. Use the horizontal calibrator line as a reference. The dead zone is adjustable from 0 to 40 volts.

HYSTERESIS Select HYST. and use the same procedure as was used for the dead zone adjustment. The width of the hysteresis loop is constant (-50 volts to +50 volts). The height is adjustable from 10 to 50 volts.



GPS DEADZONE-HYSTERESIS PATCHBOARD LAYOUT

FIGURE 11.1

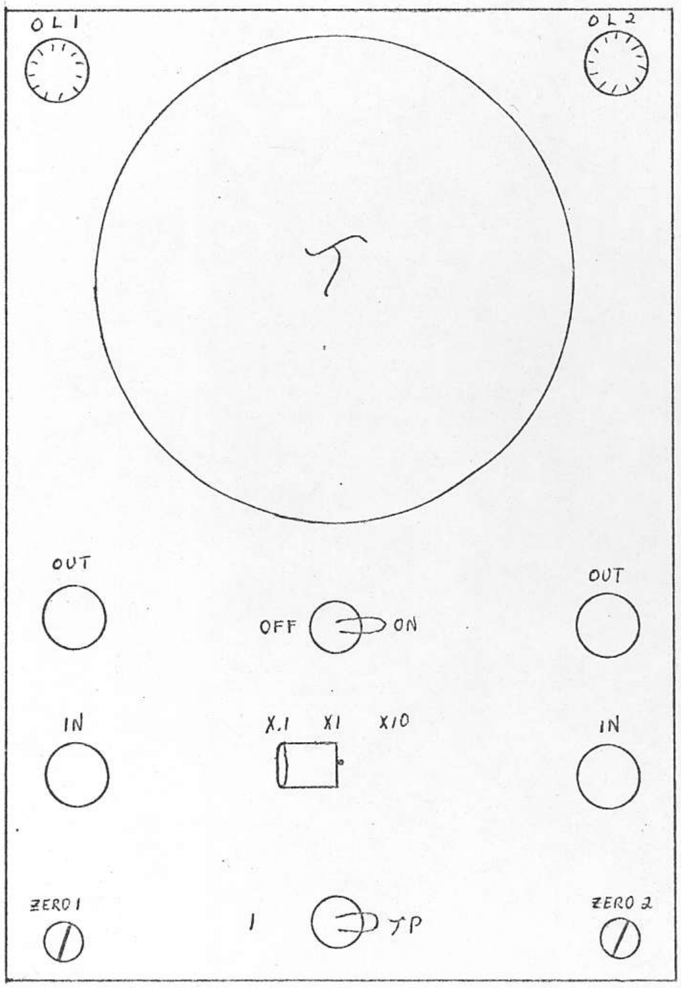
12.0 FIRST ORDER LAG

A typical first order lag (F.O.L.) is shown pictorially in FIG. 12.1. With the toggle selector in position P the input-output performance is

$\frac{E_{OUT}}{E_{IN}} = \frac{\tau P}{1 + \tau P}$ where P is the Laplace Transform variable & E_{IN} is the sum of the input voltages. With the toggle selector in position 1 the input output performance is $\frac{E_{OUT}}{E_{IN}} = \frac{1}{1+ \tau P}$

12.1 OPERATING PROCEDURE

Turn the plate power on and allow a 15 minute warm-up. Select τP on the toggle selector. Patch the OUT jack to the IN1-DIR for a scope display. Adjust ZERO 2 for zero volts out. Select position 1 on the toggle selector and adjust ZERO 1 for zero volts out. With the lever switch in X 0.1 position τ can be varied from .01 to .2 seconds, in the X 1 position .1 to 2 seconds and in the X10 position from 1 to 20 seconds.



GPS FIRST ORDER LAG PATCHBOARD LAYOUT

FIGURE 12.1

GPS ANALOG COMPUTER

13.0 NOISE UNIT

The GPS noise unit is shown in FIG. 13.1. The noise units uses a gas diode in a magnetic field as a random voltage source. The distribution of amplitudes very closely approximates the normal probability distribution. The power density spectrum is that of white noise shaped by a first order filter.

$$P.D. = \frac{1}{\pi} \qquad \frac{\tau \sigma^2}{1 + \tau^2 \omega^2}$$

τ, the time constant of the spectrum, is adjustable over a range of .01 to .4 GPS seconds. At the widest bandwidth, the output appears to be white noise to any system simulated on the GPS. The root mean square of the noise is adjustable from 0 to 6 volts.

A large number of random processes can be approximated by passing white noise through a first order filter. This capability is built into the noise unit. For a modification of the frequency characteristics refer to the GPS application note 2.

The panel meter on the noise unit can be used to indicate directly the mean value of a problem variable during the computer "on" time. This meter can also be used to measure the RMS value of a problem variable if the process is Gaussian.

MEAN VALUE To measure the mean value of a variable during the computer "on" time.

1) Select position 0. Zero the meter on both the XIO & XI positions.
2) Patch the signal into IN1 or IN2 and select the appropriate position on the input selector.
3) Select position B.

4) Use reverse bias switch for a upscale reading.

5) The average value of the input signal is

$\sqrt{\frac{2}{\pi}}$ TIMES (METER READING IN VOLTS)

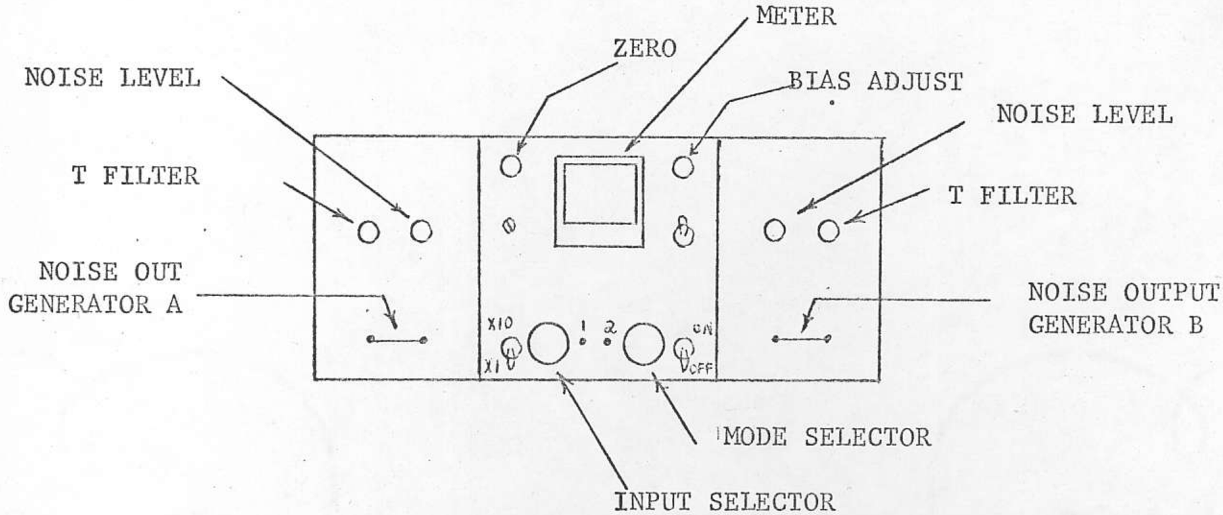


FIG 13.1 GPS NOISE UNIT LAYOUT

GPS ANALOG COMPUTER

14.0 VARIABLE DIODE FUNCTION GENERATORS (VDFG)

The GPS has two five-segment VDFG. Function generator A accepts only negative inputs and function generator B only positive. A typical function generator patchboard layout is shown in FIG. 14.2. A block diagram of the VDFG is given in FIG. 14.1.

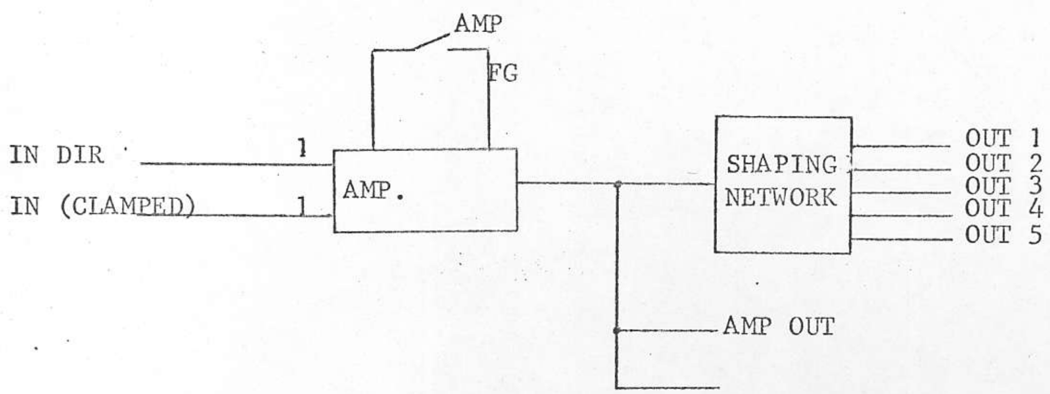


FIG. 14.1 GPS VDFG SCHEMATIC

The IN DIR jack can be used for input signals having no DC drift. The clamped input jack is the one normally used. The AMP OUT jacks provide the input variable with a minus unity gain factor. The AMP-FG toggle switch selects the mode of operation either an inverting amplifier or a VDFG.

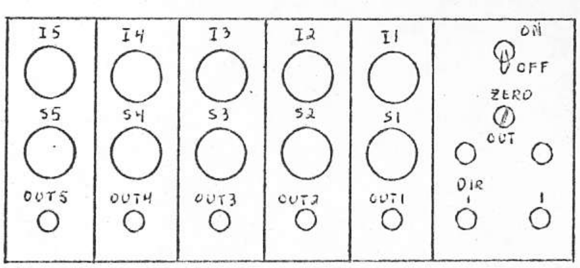


FIG. 14.2 GPS VDFG PATCHBOARD LAYOUT

The AMP-FG switch should be kept in the AMP position when the VDFG is not being used. The reason for this is to preserve the bias batteries. The OUT_i i = 1...5 jacks provide the output voltage for each line segment of the VDFG. These output jacks are normally patched to a general purpose summer inputs jacks (with appropriate gains) so that the various segments can be added together to form the function.

All five segments have slopes which are continuously variable from 0 to 1. The intercepts are continuously variable in overlapping ranges.

INTERCEPT	RANGE
I 1	0 - 2.5 volts
I 2	2.5 - 5.0 volts
I 3	5.0 - 7.5 volts
I 4	7.5 - 10.0 volts
I 5	10.0 - 13.5 volts

14.1 OPERATING PROCEDURE

Apply the plate power and allow a 15 minute warm-up. Patch the AMP OUT to IN-DIR for a scope display. Adjust the zero pot for volts out. Patch the OUT_i i = 1...5 into the input jacks of a summer. Observe the output of the summer on IN1-DIR. It is suggested that each OUT jack be patched into the summer one at a time. The breakpoint and slope of each segment can then be set without interaction from the other segments. This will also help the user to select the best summer input gains for the individual line segments.

GPS ANALOG COMPUTER

15.0 LOGIC CONTROL TRAY

The logic control tray (FIG. 15.1) is the control center for iterative operation. This tray supplies the necessary hardware to:

1) Control the starting and stopping of the iterative action.
2) Generation of tracking gates during the computer "on" and "off" time.
3) Generation of an (i+1)th gate pulse on command.
4) Generation of a transfer pulse for the S&H units.

Reference to FIG. 15.3 will aid in the understanding of the various output waveforms that are available.

TRACKING GATES The logic control tray contains three completely independent sets of tracking gates. One such unit is shown pictorally in FIGURE 15.2.

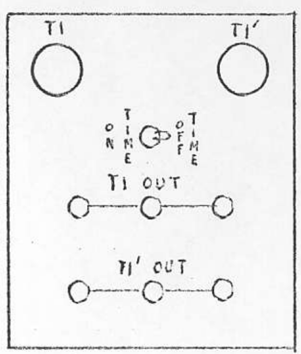
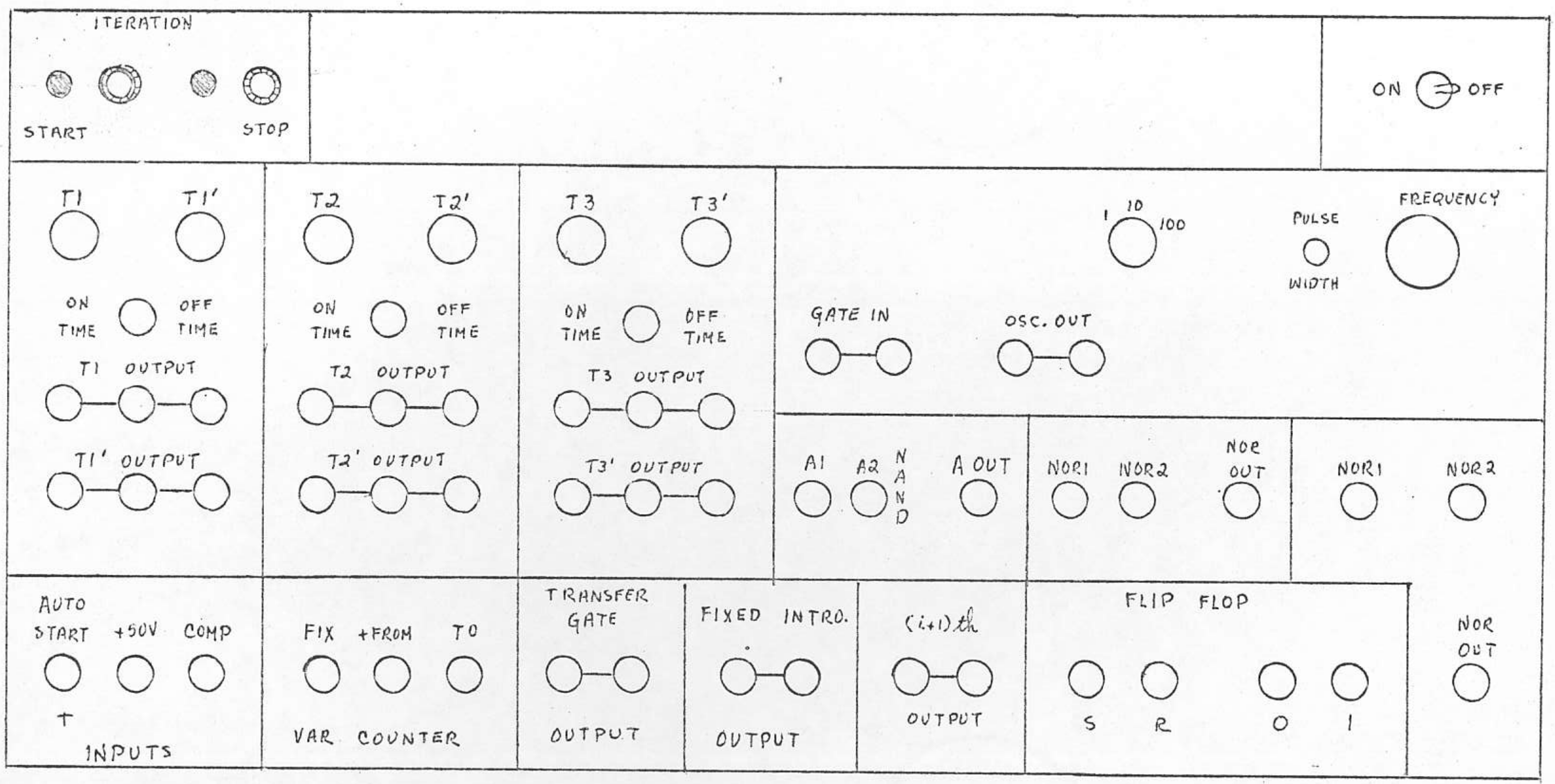


FIGURE 15.2 TRACKING GATE



GPS LOGIC CONTROL TRAY

FIGURE 15.1

PANEL CONTROLS The ON TIME/OFF TIME toggle switch determines whether the tracking signals start with the computer "on" time or "off" time. The Ti (i=1,2,3) pulse, which starts with computer ON or OFF time as selected by the toggle switch, is of variable width (9 to 400 GPS seconds). The Ti' pulse starts with the trailing edge of the Ti pulse, and its width is also adjustable from (9 to 400 GPS seconds). The output is taken from the Ti, Ti' jacks.

The logic control unit also contains a gated oscillator. The output of the gated oscillator is a pulse train having an adjustable frequency from 30Hz to 30 KHz as selected by the multiplier and calibrated pot. The pulse width is adjustable from 0 - 3 msec. The oscillator has an output when the GATE IN is high.

ITERATIVE ACTION The iterative operation may be either fixed or variable as selected by the FIX/VAR toggle switch. In the FIX position a preset counter sends out a pulse to reset the master flip flop. Once the master flip flop is reset all tracking gates and timing gates originating from the logic control become zero. In the VAR position the master flip flop will continue to operate until the iterative stop button is depressed. Once the iteration procedure is stopped it can be started either by depressing the start button or by receiving a high input signal in the AUTO START + jack. For a fixed number of iterations the TO jack should be patched to the counter input. The counter output should be patched to the +FROM COUNTER jack. See FIG. 15.1 for the location of these jacks.

The logic control tray also provides a transfer gate which is a 5 msec. pulse that starts at the computer "off" time. A typical use for a transfer gate would be to transfer a variable from one S&H to another during the "off" time.

The FIXED INTRODUCE provides a high output during the computer "on" time and a low output during the "off" time.

The (i+1)th output provides a high output during the computer "on" time whenever the COMP jack became high during the last problem cycle.

The logic control also contains one flip flop, two nor gates and one nand gate. These gates are separate from the logic signals generated by this tray and still function even though the iteration has stopped.

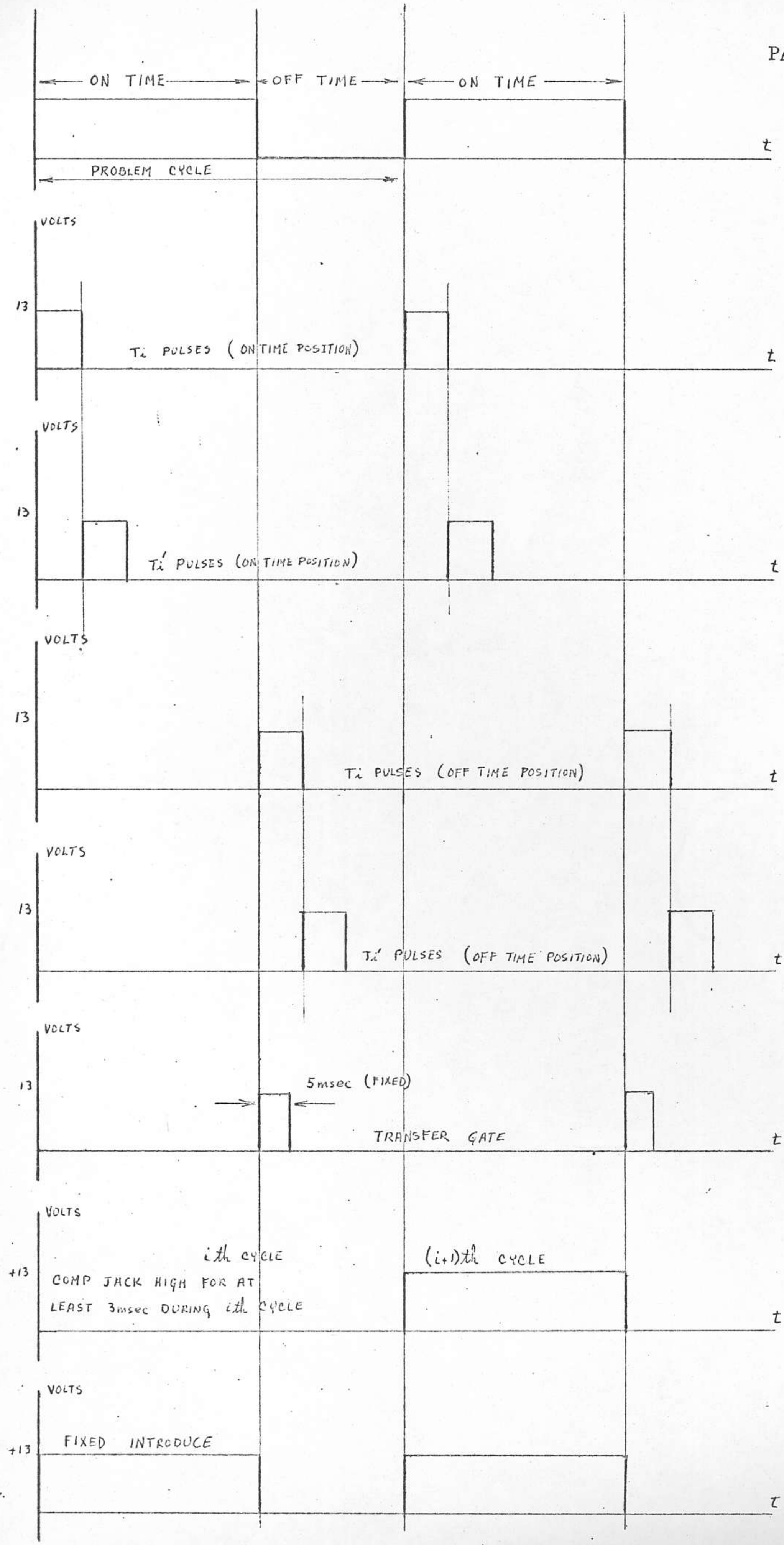

ON TIME
OFF TIME
ON TIME
PROBLEM CYCLE
t
VOLTS
13
Ti PULSES (ON TIME POSITION)
Ti' PULSES (ON TIME POSITION)
Ti PULSES (OFF TIME POSITION)
Ti' PULSES (OFF TIME POSITION)
5msec (FIXED)
TRANSFER GATE
+13
ith CYCLE
(i+1)th CYCLE
COMP JACK HIGH FOR AT
LEAST 3msec DURING ith CYCLE
FIXED INTRODUCE

FIGURE 15.3

GPS ANALOG COMPUTER

16.0 COMPARATORS

A typical comparator unit is shown below in FIG. 16.1.

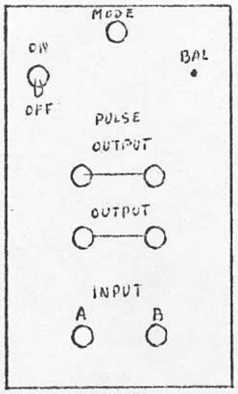


FIG. 16.1 GPS COMPARATOR PATCHBOARD LAYOUT

The comparator has an output of zero volts when the sum of its analog inputs is greater than zero and an output of +12 volts when the sum of its inputs is less than zero. A 50 usec. pulse is also generated each time the sum of the input voltages becomes negative. The mode indicator illuminates each time the sum of the analog inputs goes negative.

16.1 OPERATING PROCEDURE

Apply power to the comparator and allow 15 min. warm-up. Set both analog inputs to zero by patching red bottle plugs into inputs A & B. Set the BAL adjust so that the mode indicator just extinguishes. Patch the analog inputs into input jacks A & B. For accuracy the inputs should be from operational amplifiers. The comparator output can either be taken from the OUTPUT or the PULSE OUT jacks.

17.0 ELECTRONIC SWITCHES

A typical electronic switch is shown below in FIG. 17.1.

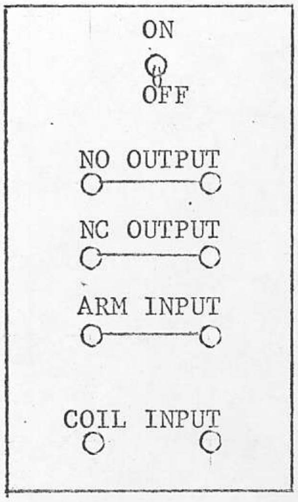


FIG. 17.1 GPS ELECTRONIC SWITCH PATCHBOARD LAYOUT

COIL INPUT The logic signal is patched to the coil input.

ARM INPUT The signal to be switched is applied to the arm input.

N.C. OUTPUT The signal on the arm input appears at the N.C. OUTPUT when the COIL INPUT is low.

N.O. OUTPUT The signal on the arm input appears at the N.O. OUTPUT when the coil input is high.

Operating Procedure Patch the signal to be switched into the arm input. Patch the logic signal and the desired output. For best results the arm input should be from an operational amplifier.

GPS ANALOG COMPUTER

18.0 MISCELLANEOUS EQUIPMENT

1) Each BCU has an eight position selector switch. The dual inputs are labeled S1 thru S8. The dual output jacks are labeled SCOPE. This switch is normally used to select signals for scope display.

2) The brown switchcraft boxes are tiepoints. They can provide any jack on the computer with two inputs. Some of these boxes have been modified and have resistors, capacitors or diodes in series with the common output lead. The contents of the modified boxes is clearly marked.

3) The red phone jacks are ground plugs.

4) The stainless steel jacks are used to patch two patchcords. together.

5) The gray boxes are attenuators having a summing junction input. The output is the sum of the inputs times the marked attenuation. .1 and .2 attenuators are available. Each attenuator has 3 input jacks.

GPS ANALOG COMPUTER

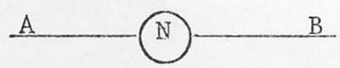
19.0 OPERATIONAL NOTES

The basic unit of time for the GPS computer is 1/3014 second, or approximately 1/3 msec. By definition 1 GPS second equals 1/3 msec. real time. The timing dots are generated by the MG every 2 GPS seconds. They are equally spaced and are independent of the sweep linearity of the display scope.

Some care should be exercised when patching the reference supplies to the problem set up. Patch to the reference supply last since the patch-cords short to ground when they are inserted into the jacks.

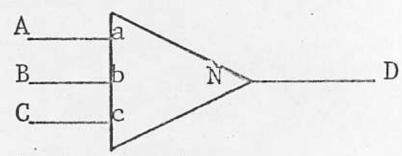
PROGRAMMING SYMBOLS

POTENTIOMETER



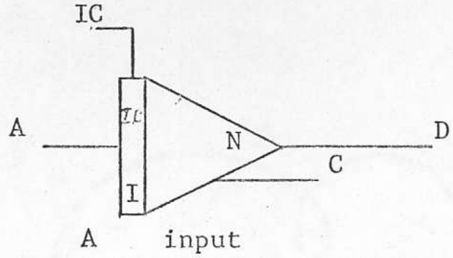
A input
B output
N component description

AMPLIFIER



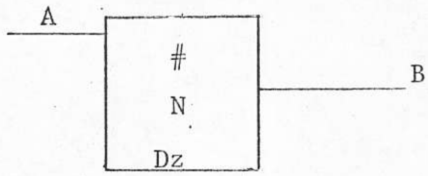
A, B, C inputs
a, b, c input gains
D output
N component description

INTEGRATOR



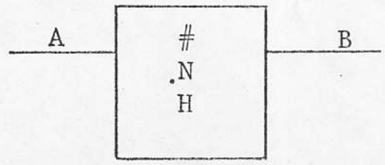
A input
I.C. initial condition
D inverted output
C output
N component description

DEAD ZONE



A	input
B	output
#	dead zone (max value)
N	description of component

HYSTERESIS

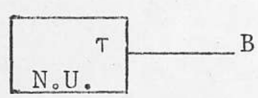


A	input
B	output
#	peak of hysteresis plot
N	description of component

TRUNK

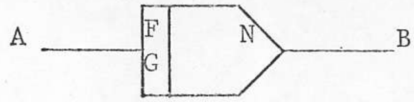
N	description of component

NOISE UNIT



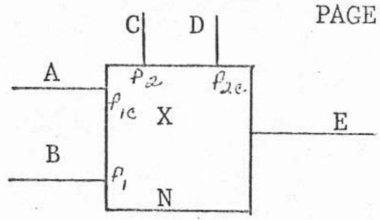
τ	setting of τ filter
B	output

FUNCTION GENERATOR



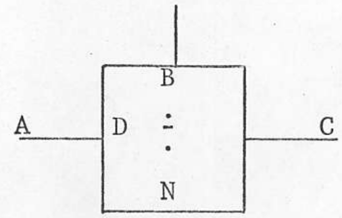
A	input
B	output
N	description of component

MULTIPLIER



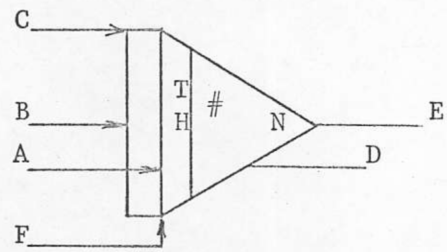
A, D	clamped input
B, C	direct input
E	output
N	component description

DIVIDER



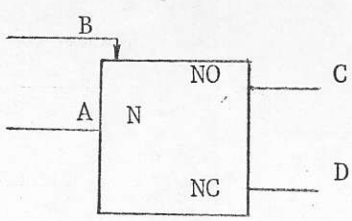
A	denominator
B	numerator
C	quotient (output)
N	component description

SAMPLE & HOLD



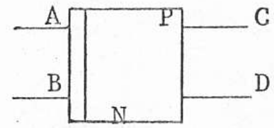
A	integrator input
B	track in input
C	command input
D	gate output
E	output
F	enable input
#	selector setting
N	description of component

ELECTRONIC SWITCH



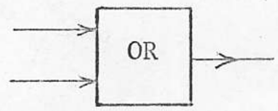
A	input
B	coil input
C	N.O. output
D	N.C. output
N	description of component

COMPARATOR

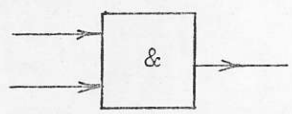


A, B   inputs
C   pulse output
D   output
N   description of component

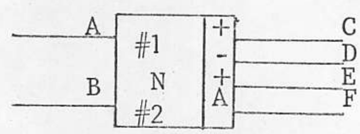
OR



AND

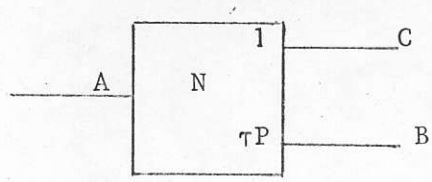


LIMITER



A, B   inputs
C   +LIM out
D   -LIM out
E   ±LIM out
F   amplifier out
#1   +LIM setting
#2   -LIM setting
N   description of component

F.O.L.



A   input
B   output with transfer function $\frac{\tau P}{1+\tau P}$
C   output with transfer function $\frac{1}{1+\tau P}$
N   description of component