NRL Report 6372

Polar Video Gating of Radar and IFF Displays Using Cartesian Control

F. R. FLUHR

Data Processing Branch
Applications Research Division

February 21, 1966

U.S. NAVAL RESEARCH LABORATORY
Washington, D.C.

CONTENTS

Polar Video Gating of Radar and IFF Displays Using Cartesian Control

F. R. Fluhr

Data Processing Branch
Applications Research Division

Many data-processing operations require the rapid and accurate extraction of position data from cathode-ray-tube information sources such as radar, IFF, and sonar PPI repeaters. An IFF Active Readout System under development required gating out IFF video responses at positions controlled by a hook position marker. In this implementation, the hook marker is presented on the PPI in x-y coordinates during the radar repeater recovery or retrace period. A means was devised of developing a video gate control which gates the video with a constant angular width and constant range depth using the x and y dc hook position voltages and the PPI repeater resolved x and y sweep voltages. The computation uses an analog approximation technique which is relatively simple. The approximation deviates from the ideal less than 0.5% for a 10° angular width gate. This deviation can be eliminated by the addition of a simple compensation scheme. The video gating method can be implemented digitally for those PPI displays using digital sweeps.

INTRODUCTION

Many data-processing operations require the rapid and accurate extraction, control, and coordination of position data from cathode-ray-tube information sources such as radar and IFF PPI repeaters. In the course of devising an IFF Active Readout System (1), a means of gating target video displayed in normal PPI ρ-θ coordinates from a hook (2,3,4) controlled in x-y coordinates became necessary. Most of the PPI repeaters now used with IFF displays such as the AN/UPA-50 use the PPI electronic cursor with its ρ-θ range mark and bearing cursor controls. Modifications to the PPI cursor circuits are made in order to derive the desired video gating signals. In order to position the video gate, the AN/SPA-8A PPI cursor is displayed once for each nine radar sweeps, causing 10 percent of the radar display time to be lost. Retrace-insertion techniques (2) are used in the present effort to display the hook position (desired video gating position) in order to eliminate the robbing of radar display time and to obtain a faster and more efficient operator control. Under these conditions the hook position coordinates are no longer available in the radar time coordinates.

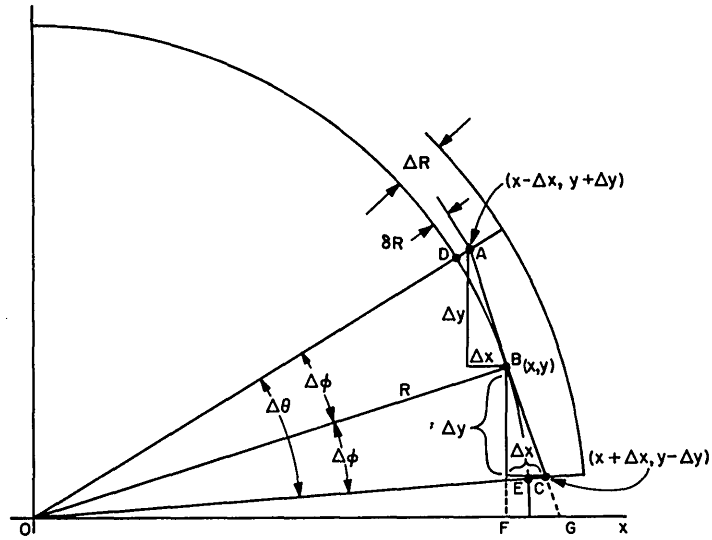
In the design of conventional devices used for the rapid control of a hook position, such as a "joystick," "bowling ball," "conducting glass electronic pencil" (2), or "light pencil" (3,4), the coordinate position voltages are available in x-y coordinate form. To use these voltages in the formation of a true range and bearing gate, cartesian (x-y) coordinates can be converted to polar (ρ-θ) coordinates by the direct mathematical means in either analog or digital computers. In addition to the position coordinate conversion, it is desirable that means be included in the computer manipulations for maintaining a constant angular width and range depth of the video gate for all possible target locations. The video gating could be done in x-y coordinates with a square gate or an octagonal gate if simple diode function generators are used (5,6).

Since the angular width of the gate would not be expected to exceed 16°, a relatively simple and close approximation to the desired video gate shape has been devised, without requiring an elaborate computer for coordinate conversion. The x-y hook coordinates in conjunction with the PPI repeater sweep signals are used to derive the video gate. The method is described and implemented in analog form, but can be implemented with simplicity advantages over other methods in the digital form for PPI displays using digital sweeps.

VIDEO GATE COMPUTATION

The video gate geometry is shown in Fig. 1. The target position is at B. It is desired to determine

NRL Problem Y01-23; Project SF 001-10-01-6106. This is an interim report; work on the problem is continuing. Manuscript submitted November 2, 1965.



OB = OD = OE = R

OA = OC = R + δR

THE LENGTH OF ARC DE IS $\Delta S = R\Delta\theta$;

BUT $\Delta S/2 \approx \sqrt{(\Delta x)^2 + (\Delta y)^2}$;

THEN $R\Delta\theta \approx 2\sqrt{(\Delta x)^2 + (\Delta y)^2}$.

FROM COMPARISON OF SIMILAR TRIANGLES, $\Delta y/\Delta y = y/x$;

HENCE $\Delta x = ky$ AND $\Delta y = kx$, WHERE k IS A CONSTANT LESS THAN ONE;

THEN $R\Delta\theta \approx 2k\sqrt{x^2+y^2}$.

BUT $R = \sqrt{x^2+y^2}$;

HENCE $\Delta\theta \approx 2k$.

THUS $\Delta x = (\Delta\theta/2)y$ AND $\Delta y = (\Delta\theta/2)x$.

Fig. 1 — Video gate geometry

points D and E, as the radial sweeps R are rotated through the target region. If it is assumed that $AB \approx DB$, and $BC \approx BE$, we can locate points A and C, which differ from points D and E, respectively, by a range deviation δR which is small when angle $\Delta\theta$ is small. To determine point A, the value of Δx must be subtracted from the voltage representing the target coordinate x at B, and the value of Δy must be added to the voltage representing y. Thereafter, simultaneous comparisons of these modified values with the x and y sweep voltages from the radar display will result in detectable coincidences at point A. By inverting the polarities of the Δx and Δy voltages, point C is similarly established.

By inspection, it was intuitively noted that Δy appeared to be proportional to the x coordinate of B, and conversely that Δx was proportional to the y coordinate of B. The geometric equations accompanying Fig. 1 show in fact that this proportionality is direct and that the proportionality factor (k) is equal to $\Delta\theta/2$. Thus the voltages for Δx and Δy are determined when x, y, and $\Delta\theta$ are established.

The straight-line approximation of the arc causes the range at the start and end of the gate to be slightly greater than at the center of the gate. The range deviations δR as a function of gate widths $\Delta\theta$ are shown in Table 1, calculated by the relation given in the table title. As indicated, an azimuth gate width of $\pm 15°$ (30° total) would have the effect of increasing the range of the gate by 3.5%, whereas a $\pm 2.5°$ (5° total) gate width would cause a range increase of only 0.1%. The gate width in normal operation would rarely exceed $\pm 2.5°$.

The value of the range coordinate R in dc form is derived in the process of determining point A.

Table 1
Range Deviation δR (Expressed as a Percentage of R) as a Function of Gate Width $\Delta\phi$, Determined From the Relation (See Fig. 1)

$$\frac{\delta R}{R} = \frac{OA - R}{R} = \frac{OA}{R} - 1 = \frac{1}{\cos \Delta\phi} - 1$$

$\Delta\phi$ (degrees)	$\delta R/R$ (percent)
0	0
1	0.001
2	0.06
3	0.14
4	0.25
5	0.40
6	0.55
7	0.75
8	0.98
.	.
.	.
.	.
15	3.53

The noted deviation, although of only minor consequence in any practical system, yields to a relatively simple compensation, rendering a no-compromise solution even out to a gate width of 90°. While this compensation is described later in this section, it may not be incorporated in the laboratory model, since it is not considered necessary in this application.

A block diagram of the video gate computer for use with a standard fixed coil PPI repeater is shown in Fig. 2. The input signals to the video gate computer are the PPI sweep voltages x_{sw}, y_{sw}, and r_{sw}, and the hook position coordinate voltages $-x_h$ and $-y_h$. The x_{sw} and y_{sw} waveforms are resolved from the R_{sw} in the PPI repeater and are in time coincidence. The hook position coordinate voltages are obtained from the hook control device.

With the PPI scanning in a clockwise direction (see Fig. 1) the $(x - \Delta x, y + \Delta y)$ point is being determined in time by the subtract/add and the add/subtract circuits. When this point is reached by the PPI sweeps, the difference amplifiers null simultaneously. The simultaneous null point is detected by the AND circuit and triggers the threshold circuit. The output of the threshold circuit passes through the buffer gate and the

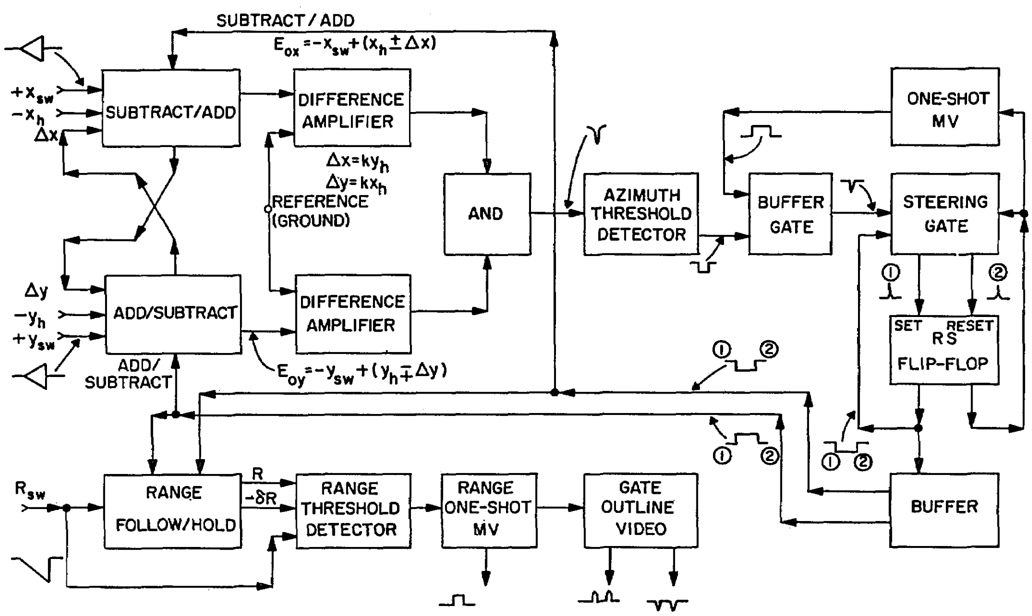


Fig. 2 — Video gate computer

steering gate and sets the *RS* flip-flop. The one-shot multivibrator output causes the buffer gate to block any extraneous pulses which may be generated by the threshold circuit immediately following the first pulse. The setting of the *RS* flip-flop also reverses the state of the subtract/add and add/subtract circuits so that the gate endpoint $(x + \Delta x, y - \Delta y)$ can be derived.

Also when the *RS* flip-flop is set, the range follow/hold circuit is switched from the follow condition to the hold condition. This causes the range of the initial gating action to be stored. During the hold condition, each subsequent range sweep is compared with the derived gate range voltage by the range threshold detector. Each time the range sweep goes through the stored value, the threshold detector triggers the range one-shot multivibrator. The width of the range multivibrator output pulse, which is controllable, corresponds to the range depth (ΔR) of the video gate. A gate outline circuit, driven by the range multivibrator, provides video pulses for painting the outline of the video gate on the PPI. In order to compensate for the range deviations due to the computation approximation, a signal δR is subtracted from the range value in the range threshold detector. The signal δR is proportional to range, and the increment is set by a control operated in tandem with the angular width control.

When the PPI scan reaches the second point $(x + \Delta x, y - \Delta y)$, the azimuth threshold detector detects the simultaneous null of the subtract/add and add/subtract circuits and generates a pulse which passes through the buffer gate and steering gate to reset the *RS* flip-flop. This resetting operation restores the video gate computer to its initial state so that it is ready to repeat the operation of generating the video gate on the next PPI scan through the hook marker position.

CIRCUITS

The video gate computer circuits for use with the AN/SPA-8A PPI repeater are shown in Figs. 3, 4, and 5. Several types and varieties of microelectronic devices from several manufacturers were used in the video gate computer to evaluate the microelectronic devices in this type of operation. Stable dc operational amplifiers with differential input were used for the add/subtract functions as shown in Fig. 3. The add/subtract function is obtained by switching the $\Delta x/\Delta y$ signal to the positive input to the operational amplifier. The transfer function (see Appendix) of the add/subtract circuit for the situation illustrated is

$$E_o = -0.2x_{sw} + \left(\frac{30}{7.5 + R_{cal}}\right)X_H - 3\Delta x + N(6\Delta x)$$

where $N = 1$ for the switch closed (add) and $N = 0$ for the switch open (subtract). The outputs of the add/subtract circuits are compared against signal ground by the two difference amplifiers. The outputs of the difference amplifiers drive a logical AND circuit. When both difference amplifiers simultaneously null, the output of the AND circuit goes low and causes the Schmitt threshold detector to trigger. The triggering of the threshold detector generates the azimuth leading edge pulse which is passed through the MμL-911 buffer gate and the MμL-910 steering gate to set the MμL-910 *RS* flip-flop. The setting of the *RS* flip-flop triggers the MμL-910 multivibrator and holds the steering gate so that any subsequent pulses from the buffer gate will reset the flip-flop. The multivibrator output inhibits the buffer gate for a period sufficiently long for the circuits controlled by the *RS* flip-flop to become stabilized. The inhibiting action blocks any subsequent pulses from the threshold detector until after the add/subtract circuits have been switched and allowed to stabilize. The setting of the *RS* flip-flop also reverses the state of the MD-985 driver circuit, which then reverses the state of the add/subtract circuits. This action allows these circuits to be ready to determine the azimuth trailing edge of the video gate. The driver circuit switches the range follow and hold circuit in Fig. 4 from the follow to the hold state.

The follow and hold circuit in Fig. 4 follows the PPI range sweep during the nongating period. When the PPI scans through the azimuth leading edge, the driver circuit of Fig. 3 reverses state and switches the circuit in Fig. 4 to the hold state. At the instant of the change to hold, the PPI range value is stored on the C_s capacitor. The capacitor C_s is within the feedback loop of an operational amplifier during the follow action by having $Q1$ cut off and $Q2$, $Q3$, and $Q6$ conducting. Thus the output of $Q5$ is an inversion of the input waveform. When the hold action is made, the transistors $Q2$,

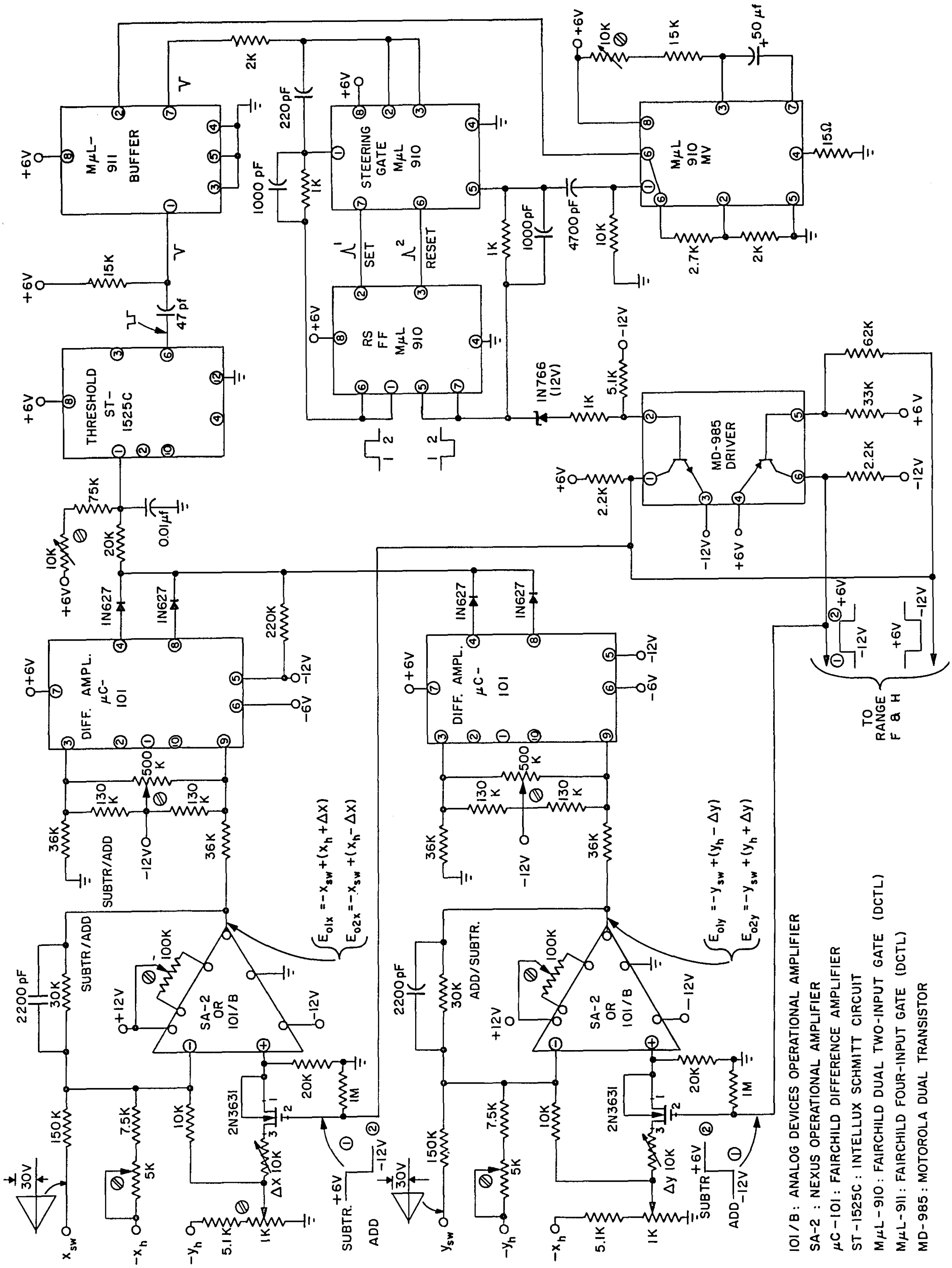
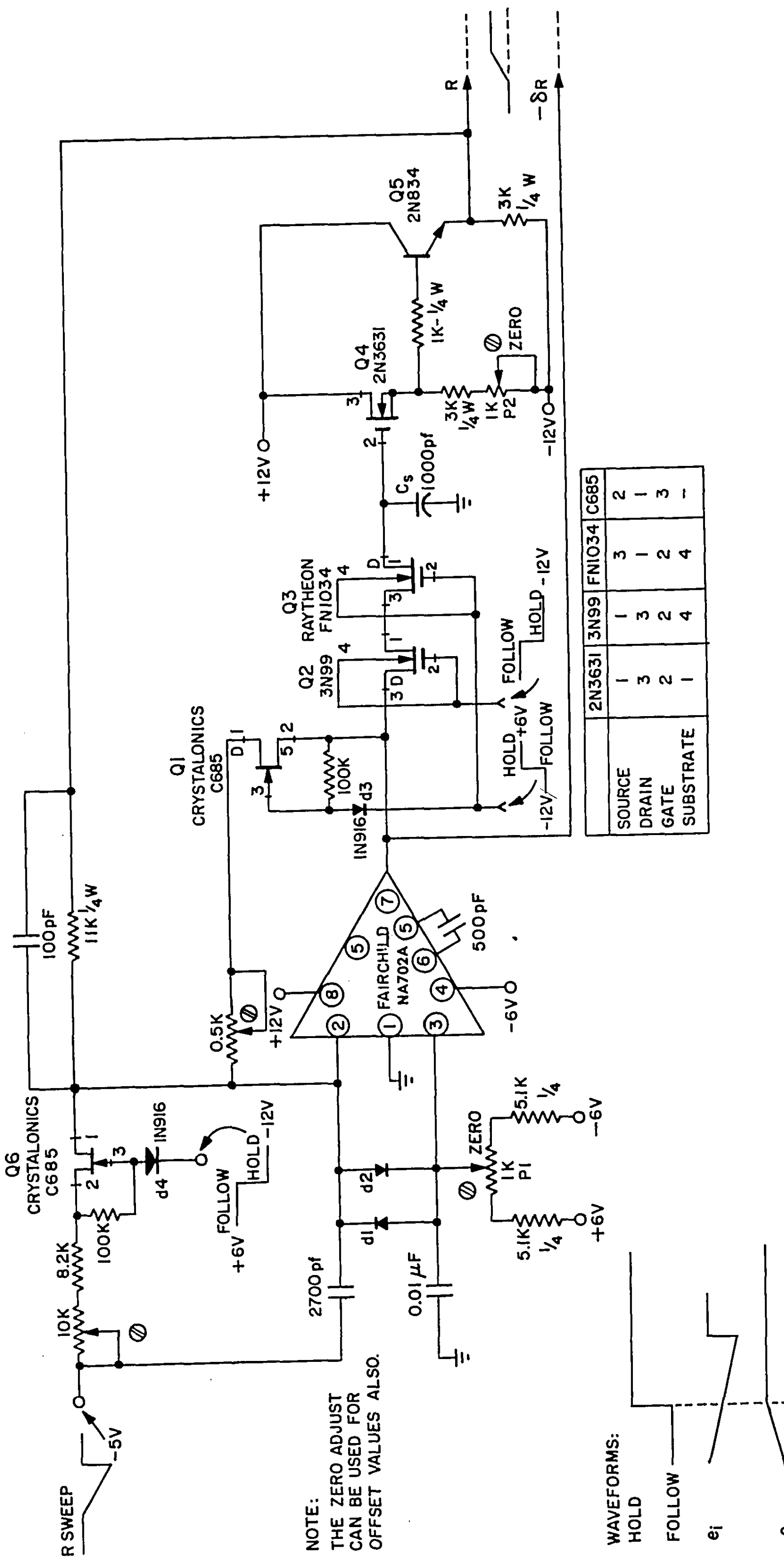


Fig. 3 — Video gate azimuth computer



	2N3631	3N99	FN1034	C685
SOURCE	1	1	3	2
DRAIN	3	3	1	1
GATE	2	2	2	3
SUBSTRATE	1	4	4	–

Fig. 4 – Range follow and hold

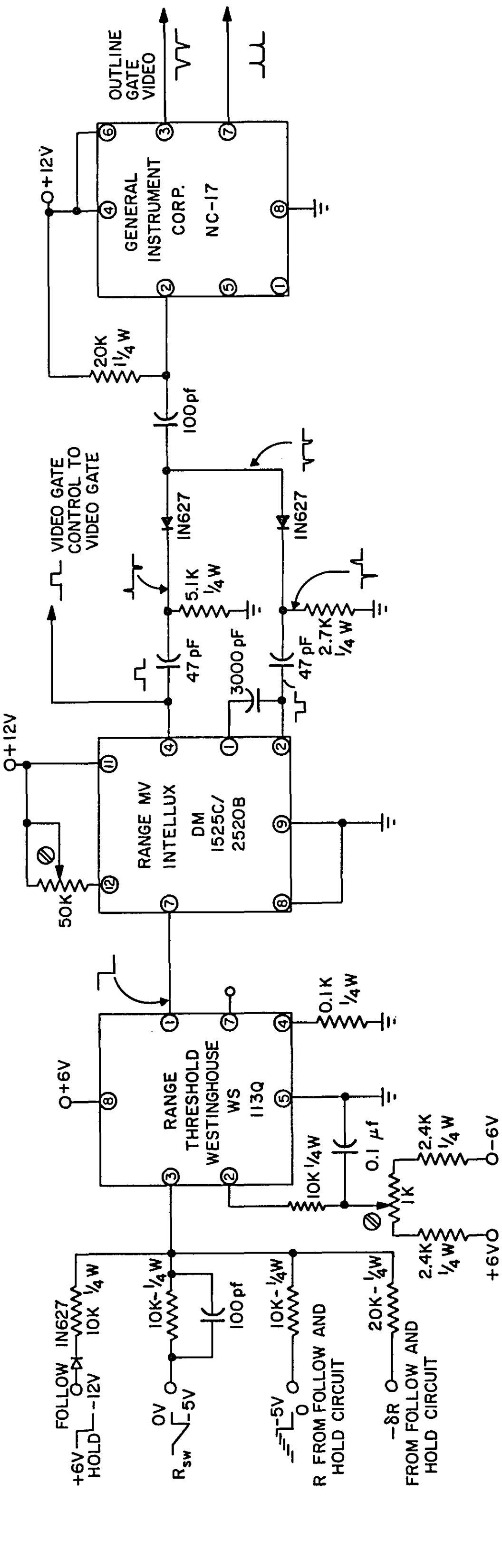


Fig. 5 — Video gate driver

$Q3$, and $Q6$ are cut off and $Q1$ is made conducting. The value of the range sweep voltage at the instant of the hold action is stored by C_s and is read out by $Q4$ and $Q5$. By turning $Q1$ on and $Q6$ off, the feedback path of the amplifier is set at a gain value which is proportional to the compensation value δ. The output of $Q5$ provides the input range R to the amplifier, thus causing the output of the μA702 to provide the compensation $-\delta R$ during the hold period. The use of an n-channel (3N99) metal-semi-conductor (MOS) in series with a p-channel (FN1034) MOS reduce the leakage current through the switch $Q2$-$Q3$ to a small value. The MOS 2N3631 has a very high input impedance and consequently very low leakage. Thus the storage capacitor C_s will hold the derived range voltage for the period of the video gating with negligible degradation. C_s must be a low-leakage, low-dielectric storage capacitor.

After the hold action takes place, the range threshold detector (Fig. 5) is released. The subsequent range sweeps are then compared to the derived range voltage less the compensation δR from the follow and hold circuit. Each time the range sweep voltage passes through the derived compensated range voltage, the range threshold detector triggers the range one-shot multivibrator. The output period of the multivibrator is set to provide the desired range depth of the video gate. The output of the range multivibrator provides the video gate control signals for use in the Active Readout Display System. In order to outline the video gate, when desired, the output of the range multivibrator is differentiated and mixed in a diode *OR* circuit. The output of the *OR* circuit triggers a Schmitt circuit which provides the required short-rise-time pulses for driving the PPI video amplifier.

SUMMARY

A video gating technique, which uses the resolved *x-y* sweep voltages from a radar PPI repeater and the *x-y* position voltages from the hook (or gate) control, has been devised to provide a constant angular width and range depth video gate control. Without compensation the angular gate width can be extended up to 16° with less than 1% range deviation. With a simple computation circuit the gate width could be extended to 90° without compromise if needed. The computation is relatively simple and has been implemented in analog form. The method can be implemented digitally for PPI display systems which use digital sweeps.

A follow and hold circuit for deriving the gate range from the *x-y* inputs has been developed. The drift of the range voltage during the video gate period is negligible.

As implemented the video gating method can be used with any standard fixed-coil PPI repeater. Microelectronic devices were used wherever possible in order to check their usefulness in switched analog systems. The circuits have operated with an AN/SPA-8A PPI repeater using the Light-Pencil Coordinate Positioner as the hook control.

ACKNOWLEDGMENT

The author wishes to express appreciation for the contributions, efforts, and assistance given by the Combined Systems Section of the Data Processing Branch.

REFERENCES

1. Fluhr, F.R., "IFF Active Readout Control and Display System," NRL Report 6277, September 1965
2. Fluhr, F.R., "The Naval Data Handling System Pickoff Display Converter," NRL Report 5248, January 1959
3. Fluhr, F.R., "Light-Pencil Coordinate Positioner," NRL Memorandum Report 1592, March 1965
4. White, W.D., "Position Correcting Means for Track-While-Scan Channels," U.S. Patent 2,849,707, August 26, 1958
5. Benjamin, R., "A Simple Circuit for the Evaluation of $(X^2 + Y^2)^{1/2}$," Great Britain, Admiralty Signal and Radar Establishment, ASRE Technical Note NX/49/1, January 19, 1949
6. Benjamin, R., "Further Developments in Resistance-Diode Function Generators," Great Britain, Admiralty Signal and Radar Establishment, ASRE Technical Note NX/49/6, March 2, 1949

BIBLIOGRAPHY

1. Valley, G.E., Jr., and Wallman, H., editors; "Vacuum Tube Amplifiers," New York:McGraw-Hill (1948)
2. Chance, B., Hughes, V., MacNichol, E.F., Sayre, D., and Williams, F.C., editors; "Waveforms," New York:McGraw-Hill (1949)
3. Roehr, W.D., editor, "Switching Transistor Handbook," 1st edition, Phoenix, Arizona, Motorola, Inc., Semiconductor Products Division (1963)
4. Warner, R.M., Jr., and Fordemwalt, J.N., editors, "Integrated Circuits," New York:McGraw-Hill (1965)
5. Schmitt, O.H., "A Thermionic Trigger," *J. Sci. Instr.* **15**:24 (1938)

Appendix

USE OF A DIFFERENTIAL-INPUT OPERATIONAL AMPLIFIER AS THE ADD/SUBTRACT COMPUTER

The method of using a single differential-input operational amplifier as the add/subtract computer is outlined below. From Fig. A1, which shows the amplifier configuration,*†

$$E_o = -ACV + BCE_4$$

and

$$V = \frac{\dfrac{E_1}{R_1} + \dfrac{E_2}{R_2} + \dfrac{E_3}{R_3} + \dfrac{E_o}{R_f}}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_f}}$$

where R_f is the feedback resistance. Thus,

$$E_o = \frac{-AC\left(\dfrac{E_1}{R_1} + \dfrac{E_2}{R_2} + \dfrac{E_3}{R_3}\right) + \left(\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_f}\right)BCE_4}{\left(\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1+AC}{R_f}\right)}.$$

If the gain of the C section of the amplifier is very large ($C \rightarrow \infty$) and if $A \approx B$, then

$$E_o = -\frac{R_f}{R_1}E_1 - \frac{R_f}{R_2}E_2 - \frac{R_f}{R_3}E_3 + \left(1 + \frac{R_f}{R_1} + \frac{R_f}{R_2} + \frac{R_f}{R_3}\right)E_4.$$

For the purpose of add/subtract, E_4 is to be equal either to zero, which is the subtract condition, the condition in which E_o is a combination of $-E_1$, $-E_2$, and $-E_3$, or to kE_3, where k is assigned a value which causes E_o to be a combination of $-E_1$, $-E_2$, and $+E_3$, which is the add condition. To allow either condition the expression for E_o can be rewritten as

$$E_o = -\left(\frac{R_f}{R_1}E_1 + \frac{R_f}{R_2}E_2\right) + \left[k\left(1 + \frac{R_f}{R_1} + \frac{R_f}{R_2} + \frac{R_f}{R_3}\right) - \frac{R_f}{R_3}\right]E_3.$$

For the subtract condition, $k = 0$. For the add condition, $k > 0$ is chosen such that

$$k\left(1 + \frac{R_f}{R_1} + \frac{R_f}{R_2} + \frac{R_f}{R_3}\right) - \frac{R_f}{R_3} = \frac{R_f}{R_3}$$

or

$$k = \frac{2\,R_f/R_3}{1 + \dfrac{R_f}{R_1} + \dfrac{R_f}{R_2} + \dfrac{R_f}{R_3}}.$$

To more readily permit k to be either this value or zero the expression for E_o can be rewritten as

$$E_o = -\left(\frac{R_f}{R_1}E_1 + \frac{R_f}{R_2}E_2\right) + \left(\frac{2\,R_f}{R_3}N - \frac{R_f}{R_3}\right)E_3$$

where $N = 0$ for the subtract condition and $N = 1$ for the add condition.

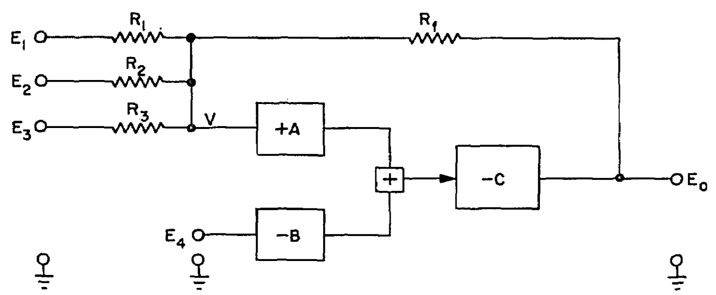


Fig. A1 — Operational amplifier configuration

*G. A. Korn and T. M. Korn, "Electronic and Hybrid Computers," New York:McGraw-Hill, 1964, pp. 1-9 through 1-16.
†H. D. Huskey and G. A. Korn, editors, "Computer Handbook," New York:McGraw-Hill, 1962, pp. 2-8 through 2-40.

For the case illustrated in Fig. 3, $E_1 = x_{sw}$, $E_2 = -x_h$, $E_3 = \Delta x$, $R_f = 30$ kilohms, $R_1 = 150$ kilohms, $R_2 = 7.5$ to 12.5 kilohms, and $R_3 = 10$ kilohms. Thus

$$E_o = -\frac{x_{sw}}{5} + \frac{30}{R_2} x_h + (6N - 3)\Delta x.$$

The expression is the same for the y channel. The resistor R_2 was made variable in order to calibrate the hook signals to the PPI sweep signals. The value of R_2 is $7.5 + R_{cal}$ in kilohms; therefore

$$E_o = -0.2x_{sw} + \left(\frac{30}{7.5 + R_{cal}}\right)x_h + (6N - 3)\Delta x.$$

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (*Corporate author*) U.S. Naval Research Laboratory Washington, D.C. 20390	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

POLAR VIDEO GATING OF RADAR AND IFF DISPLAYS USING CARTESIAN CONTROL

4. DESCRIPTIVE NOTES (*Type of report and inclusive dates*)

An interim report on the problem.

5. AUTHOR(S) (*Last name, first name, initial*)

Fluhr, F. R.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
February 21, 1966	14	6

8a. CONTRACT OR GRANT NO. NRL Problem Y01-23 b. PROJECT NO. SF 001-10-01-6106 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NRL Report 6372 9b. OTHER REPORT NO(S) (*Any other numbers that may be assigned this report*)

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Department of the Navy (Bureau of Ships)

13. ABSTRACT

Many data-processing operations require the rapid and accurate extraction of position data from cathode-ray-tube information sources such as radar, IFF, and sonar PPI repeaters. An IFF Active Readout System under development required gating out IFF video responses at positions controlled by a hook position marker. In this implementation, the hook marker is presented on the PPI in x-y coordinates during the radar repeater recovery or retrace period. A means was devised of developing a video gate control which gates the video with a constant angular width and constant range depth using the x and y dc hook position voltages and the PPI repeater resolved x and y sweep voltages. The computation uses an analog approximation technique which is relatively simple. The approximation deviates from the ideal less than 0.5% for a 10° angular width gate. This deviation can be eliminated by the addition of a simple compensation scheme. The video gating method can be implemented digitally for those PPI displays using digital sweeps.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Display systems Identification systems Plan position indicators Position finding Data processing systems Azimuth gating Range gating						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
____."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
____."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS), (S), (C), or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.