BELLCOMM ACTIVITIES ON PROGRAMMERS FOR UNMANNED APOLLO MISSIONS

(Interim Progress Report)

March 13, 1964

Bellcomm, Inc.
Washington, D. C.

By: C. M. Klingman
J. L. Marshall

Work Performed for Manned Space Flight, National Aeronautics and Space Administration, as part of Task 16-4 under Contract NASw-417.

TABLE OF CONTENTS

ABSTRACT

This report outlines the progress which Bellcomm has made towards completing the first two tasks listed in Section 4.0, "Plans for Further Work", of the Bellcomm report entitled Bellcomm Activities on Programmers for Unmanned Apollo Missions dated February 28, 1964.

Specific modifications to the AGC input/output circuitry that may be necessary in order to use the AGC as prime sequencer are discussed. Consideration is also given to the amount of AGC memory available for mission sequencing programs and the amount of time during which the AGC is available for executing these programs.

It is concluded that it appears entirely feasible to use the AGC to perform both the mission sequencing functions and the normal guidance functions.

BELLCOMM ACTIVITIES ON PROGRAMMERS FOR UNMANNED APOLLO MISSIONS

1.0 INTRODUCTION

This report outlines the progress which Bellcomm has made towards completing the first two tasks listed in Section 4.0, "Plans for Further Work", of the Bellcomm report entitled Bellcomm Activities on Programmers for Unmanned Apollo Missions dated February 28, 1964.

2.0 CONFERENCE AT MIT/IL

Bellcomm personnel visited MIT/IL on March 4 to:

1. Obtain information on how the input/output capabilities of the Apollo guidance computer (AGC) might be expanded should using it as the prime sequencer for unmanned missions require such expansion.
2. Obtain MIT's latest estimates of the amount of AGC memory which may be utilized for performing non-G&N functions.
3. Obtain MIT's latest estimates of the amount of time that the AGC would be available for performing mission sequencing functions assuming that the AGC would still perform the G&N functions.

3.0 FEASIBILITY OF USING AGC AS PRIME SEQUENCER

Based on the information received from MIT/IL at this meeting and on previous knowledge of the AGC, it appears entirely feasible to use the AGC to provide both mission sequencing and the normal guidance functions. Specific modifications that may be necessary in order to use the AGC as prime sequencer can now be discussed in considerable detail. It should be emphasized, however, that the purpose of this report is not to specify these modifications but rather to illustrate their feasibility.

3.1 Output

The output capability of the AGC can be expanded quite easily by utilizing the 143 relays presently existing in the display and keyboard (DSKY) on the main panel. These relays are operated under control of the computer (by means of the DSKY program) and are normally used for operating lights on the display panel. On manned missions, these lights provide the means for the computer to communicate with the astronauts. The keyboard in turn provides the means for the astronauts to communicate with the computer. There are presently two such DSKY units, one mounted on the navigation panel and one on the main display panel.

The easiest method of utilizing these relays would be to merely rewire the contacts of the relays but leave the decoding circuitry in the DSKY as it is now.* This decoding circuitry is used to translate four bits to a selection of one out of 13 rows of eleven relays as shown in the upper portion of Figure 1. The disadvantage to this approach is that one must guarantee that

---

* The present DSKY outputs are not as described in MIT report, R-393. No transient problems exist with the present design.

when the contacts of these relays are being used for sequencing functions, the relays are not operated by the DSKY program. This implies that the present DSKY program could not be used once the contacts of the relays in the DSKY on the main panel have been rewired. The inability to use this DSKY program in connection with the DSKY on the navigation panel as a means of communicating with the AGC prior to launch is a serious disadvantage and should be avoided.

One means of avoiding this situation is by using a different decoding scheme for selecting the relays used for sequencing functions. Figure 1 illustrates how this might be done. As shown in the figure, with the present decoder, if all four of the high order bits of the output register are 0's, none of the 143 relays will be operated or released. Therefore, if the decoder for selecting the relays for sequencing functions will only accept all 0's in the four high order bits as a valid code, there is no problem of having the DSKY and control programs interfering with one another. This method of selecting control relays leaves 11 bits for selecting particular discrete outputs. Consequently, the upper limit would be 1,024 discrete outputs. This would be possible by using 10 of the 11 bits to select any one of the 1,024 relays and one bit to specify whether to operate or release the relay selected. Although the amount of decoding circuitry required for selecting one out of 1,024 relays might well be considered excessive, it is felt that it would be quite reasonable to expand to 320 discrete points as shown in Figure 1.

There are two possibilities of how these 320 relays and associated decoding circuitry might be mounted in the spacecraft. One would be to remove the DSKY on the main panel and use this space. Another would be to leave the DSKY on the main panel but break out the leads from the output register and cable them to wherever this additional circuitry may be mounted. The advantage of this latter approach might be a quicker change from manned to unmanned missions and vice versa.

In conclusion it may be stated that extending the output capabilities of the AGC presents no significant problems.

3.2 Input

The complexity of any additional circuitry to extend the present input capabilities of the AGC will be dependent upon 1) the number of inputs, 2) whether inputs must cause interrupt of the AGC, 3) the speed at which inputs must be sampled by the AGC, and 4) whether the input signals are analog, discrete, or both.

The simplest means of getting information into the AGC would be as illustrated in Figure 2. As shown, discrete inputs are sampled five at a time by means of the computer sequentially operating relays a through x. These 24 relays would be a portion of those used for AGC outputs. The additional 120 relays (designated 0 - 119) are operated by outputs from the In-Flight Test System (IFTS). The IFTS will produce a discrete output on a particular lead whenever the comparator circuit finds the corresponding analog input signal out of limits. Obviously other discretes than the 120 available from the IFTS could be read into the computer by this means.

The voltage (+V) shown in Figure 2 would be supplied by the AGC and not the IFTS. This is necessary to provide DC isolation between the two units. It should be noted that the 120 relays (designated 0 - 119) and diodes represent additional circuitry. The five input "OR" gate and interrupt circuitry are presently part of the AGC with the exception of the relay contact shown on the lead going to the interrupt circuitry. The purpose of this contact is to prevent the inputs being sampled from interrupting the computer.

It should be noted that no inputs will come from the DSKY unless its pushbuttons are manually operated. Therefore, there is no problem of interference from the DSKY.

Although not shown, there is a signal from the IFTS on a common output, called the Master-out-of-Limits Bus, whenever any one of the 120 inputs is found to be out of limits. Therefore, instead of periodically sampling all of the 120 leads, the computer might first sample this one output to determine if any one of the 120 input signals to the IFTS is out of limits. If it is desirable to interrupt the computer when any input is out of limits, this one output might be used as an interrupt source.

An advantage of using the IFTS to expand the input capabilities of the AGC is that the AGC would not be loaded with the time consuming task of comparing inputs with pre-determined limits. A limitation of using this method of getting inputs into the AGC is that the computer does not have the ability of reading analog inputs and comparing them with each other. To do this would require that an analog to digital conversion be made on the inputs to be read in. After this conversion, the digital information could then be read into the computer five bits at a time as described for reading the outputs from the IFTS.

If the number of analog values to be read into the computer is quite large, it might be more practical to use a system such as the one illustrated in Figure 3. This would require the design and fabrication of the circuitry necessary for the computer and PCM system to communicate with each other, but would allow for using all of the A/D conversion capabilities of the PCM system. A distinct disadvantage of using this system is that the computer must perform the task of comparing all inputs with pre-determined limits. Also there is no external source of interrupt to notify the computer when any one of the inputs is out of limits.

One other point to be mentioned is that there is a 15 bit register in the AGC which is presently not used. This could be used as either an input or output register; some modifications would have to be made in the AGC to obtain access to it. If this access were provided, the limitation of reading inputs five at a time would be removed.

3.3 Memory

Approximately half (12,000 words) of the fixed memory is available for mission sequencing programs. The amount of variable memory available for use by mission sequencing programs is dependent upon the degree to which the G&N programs and mission sequencing programs time share this memory. Although both programs will require a fixed amount of variable memory to be set aside for storing variables to be retained for long periods of time, MIT's concept is that portions of the rest of the variable memory should be time shared between the G&N programs and mission sequencing programs. This implies more interleaving of the two programs than if each program used its own portion of variable memory. However, it is apparent that the amount of variable memory sharing that might be required is dependent upon the G&N objectives on these flights. The total amount of variable memory available for mission sequencing programs (both with and without memory sharing) can be increased by eliminating some G&N objectives such as testing the navigation routines.

3.4 Time

The portion of any time period during which the AGC is available for performing mission sequencing functions depends upon the particular G&N functions performed during the time period in question. Estimates are that the lowest percentage of time that would ever be available for execution of mission sequencing programs would be 10%. This would occur during powered maneuvers. On the average, the time available might be 50%, and there are times when nearly 100% of the time would be available.

Since it is expected that very few sequencing functions will be required during powered maneuvers, it is felt that the portion of time during which the AGC is available for performing sequencing functions is adequate.

3.5 Programming

The programming of the mission sequencing functions for the AGC might well represent a serious problem. It should be emphasized that the problem is not technical, but rather a result of having two different organizations (more than 2,000 miles apart) closely interfacing with each other. The first question that arises is where the interface should occur. One approach is to have NAA write and debug their own programs and have MIT perform the task of transforming the programs into a fixed memory after first verifying that they do not interfere with any of the G&N programs. Another approach is to have NAA provide flow diagrams of what sequencing functions are to be performed and have MIT write, debug, and fabricate the fixed memory. MIT is strongly in favor of the latter approach on the basis that it would be faster and more reliable.

The question of who should do the programming can probably best be answered when it has been determined how much interleaving of programs will be required. This requires that the number and type of sequencing functions be defined.

4.0 CONCLUSIONS

From the work performed thus far, the following conclusions may be drawn:

1. It appears entirely feasible to use the AGC to perform both the mission sequencing functions and the normal guidance functions.
2. The output capabilities of the AGC can easily be extended if necessary.

3. Expansion of the input capabilities of the AGC is practical. However, since the means for accomplishing this expansion is dependent upon the number and type of inputs, further definition of the inputs is required before the best approach can be chosen.

4. The portion of variable and fixed memory available for mission sequencing functions appears to be adequate.

5. The portion of time during which the AGC is available for performing mission sequencing functions appears adequate.

6. The problem of writing, debugging, and fabricating the programs for the mission sequencing functions requires a close interface between NAA and MIT. The place at which this interface should occur will probably depend upon the amount of program interleaving which must exist.

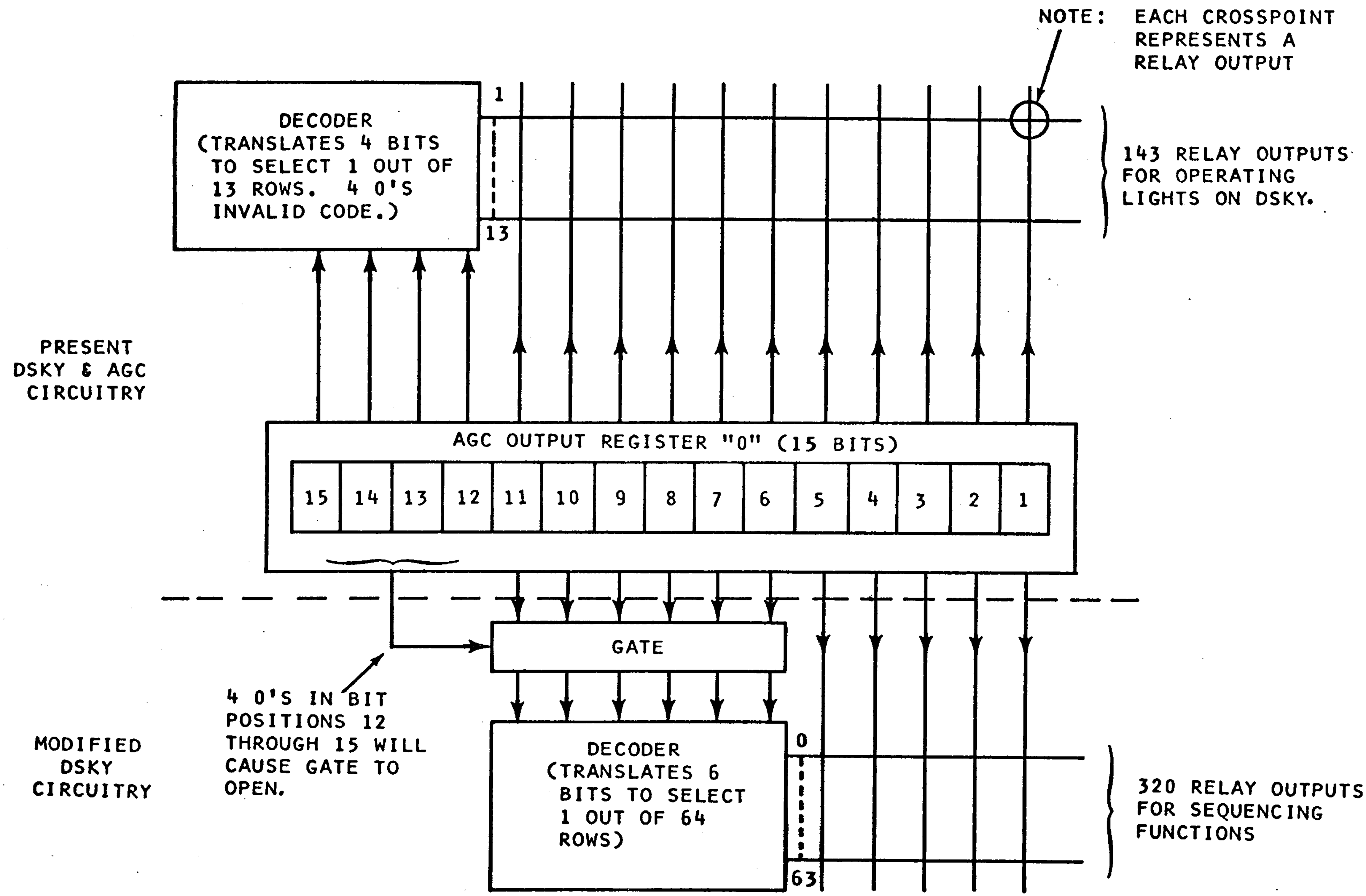

FIGURE 1 A METHOD OF EXPANDING AGC OUTPUT CAPABILITIES

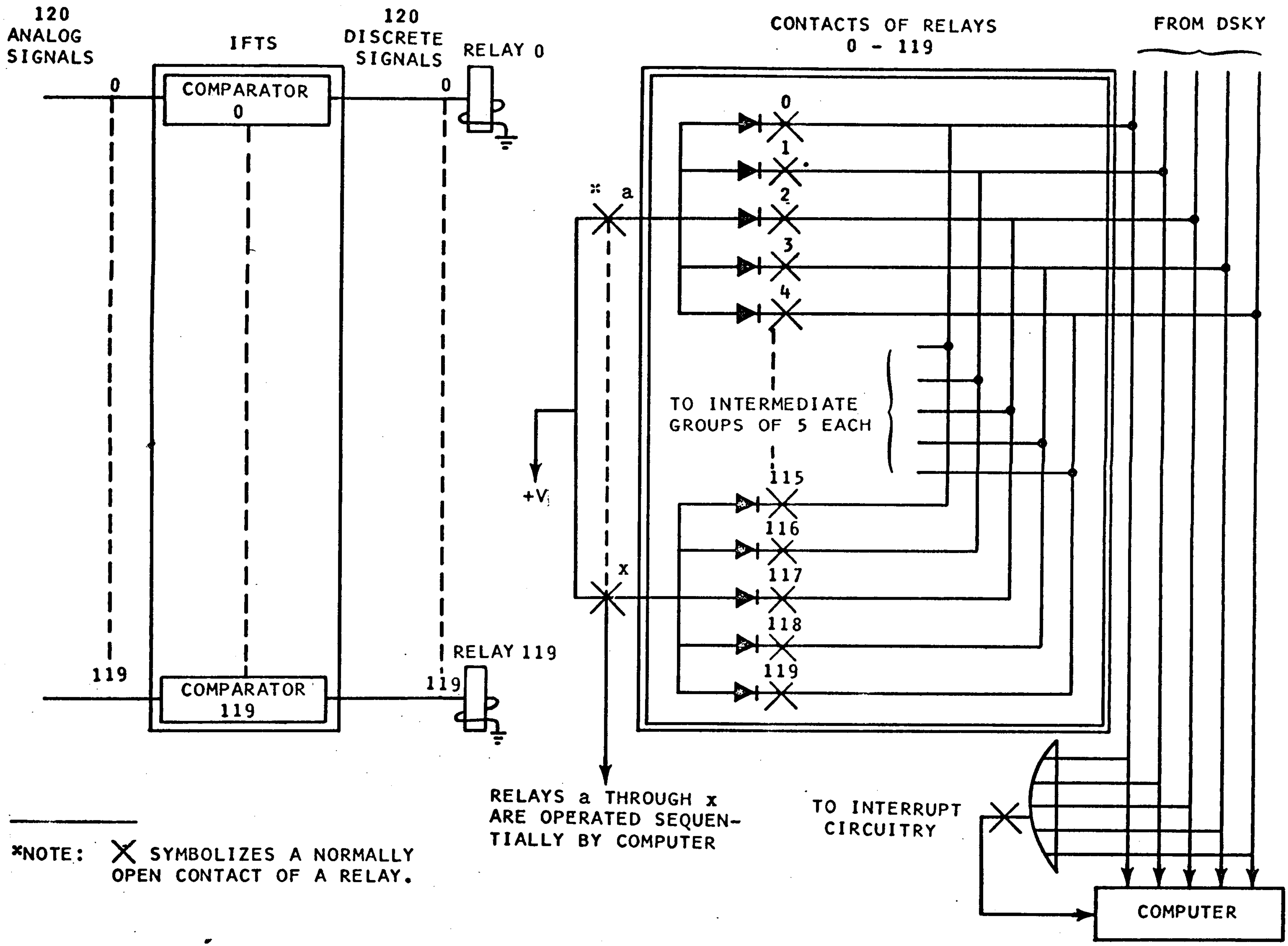

FIGURE 2 A METHOD OF EXPANDING AGC INPUT CAPABILITIES

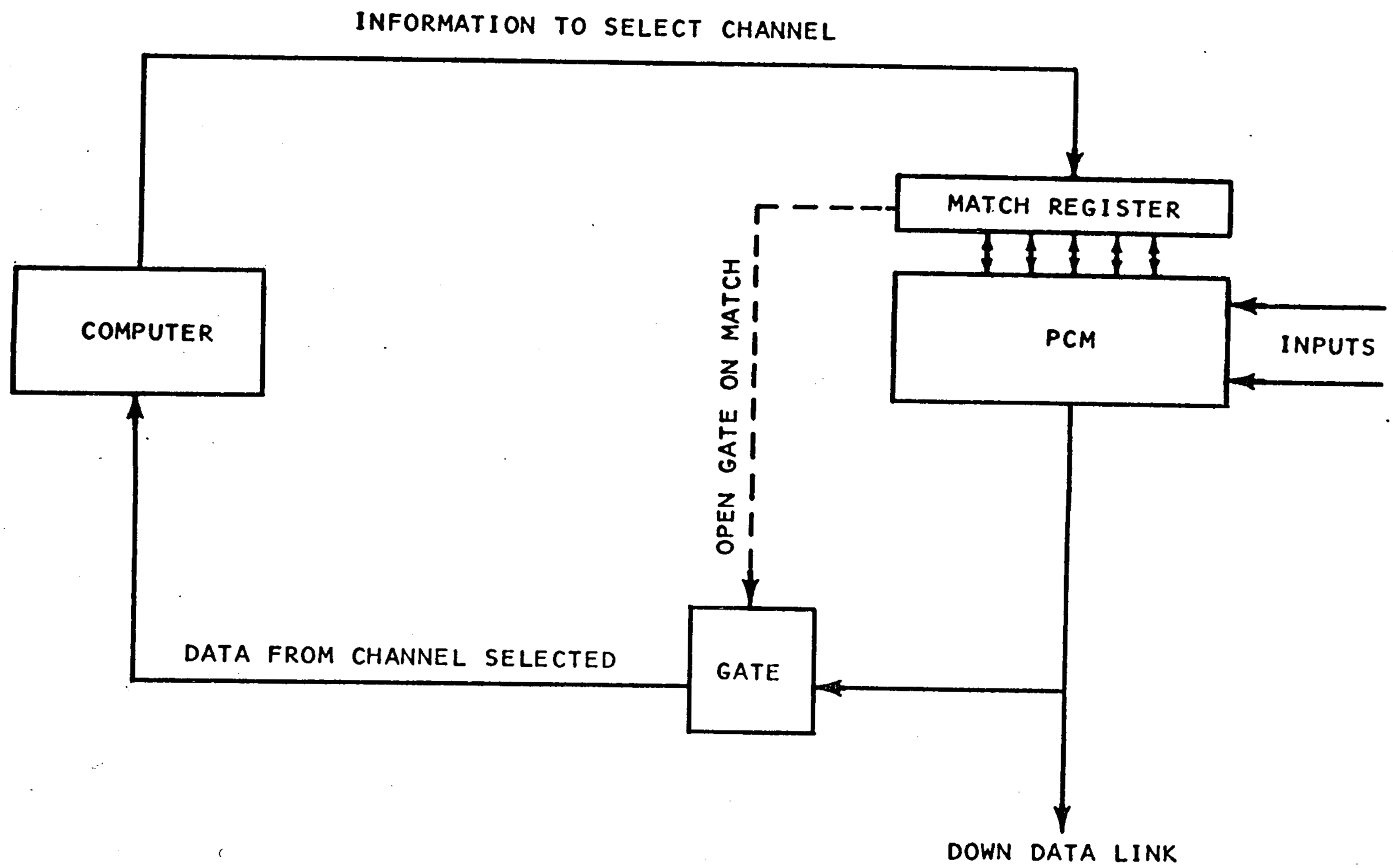

FIGURE 3 A METHOD OF EXPANDING AGC INPUT CAPABILITIES