COMPANY CONFIDENTIAL

July 2, 1956

STRETCH COMPONENTS

by: J. C. Logue

Introduction

The success or failure of the STRETCH Program depends in a large measure on the success of the component effort. While this is true of every machine that has ever been built, it is particularly true of STRETCH. Other machines have incorporated one or two new components into their design, they, in general, did not base their success on all new components. Many of the components that were used in past machines were considered initially to be standard items, but they turned out to be more complicated than first anticipated. In this respect, the STRETCH Program is different than past machine efforts. We cannot point to any component that we plan to use and say that its characteristics are known.

Why then do we have the optimism, which everyone in the program exhibits, to tackle such a task? One reason is that we feel the time is ripe for such a program. Another, and more important reason is that we feel we have an excellent physical research, component research, and manufacturing effort to back us up. Since the success or failure of STRETCH depends so strongly on research support, the feasibility phase of the program has been initiated within the research organization.

High Speed Memory

As was mentioned previously, we plan to use a 1/2 microsecond and a 2 microsecond memory. The 2 microsecond memory will be based on coincident current selection. In order to achieve the 2 microsecond cycle, it is necessary to use a ferrite core material with a high coercive force. In order that the half-select current does not exceed about one ampere, we must use an extremely small core. The cores for this memory will have an inside diameter of .030 inches, with a radial wall thickness of .010 inches.

To achieve the 0.5 microsecond cycle that the high-speed memory will have, it was necessary to depart from the usual approach, which is to use coincident current selection techniques. Severe technical difficulties prohibit our using the usual coincident current selection in order to achieve a 0.5 microsecond memory cycle. Rather than a brute force approach, we plan to modify the structure of the memory cell so that a magnetic field that is many times the coercive force of the material will be available for switching. Mr. Lawrence has described this method of operation in some detail. Paper entitled "High Speed Magnetic Storage" by W. W. Lawrence presented at the IBM Engineering-Research Conference at Syracuse University on June 18, 1956.

If other methods present themselves which will allow us to achieve a reliable high speed memory at a reasonable cost, we will naturally give them serious consideration.

Packaging

The problem of packaging for the STRETCH Machine is indeed a formidable one. When you consider that there will be upwards of 50,000 transistors in this machine, our packaging problems cause those of the American Can Company to pale to insignificance by comparison.

One of the major problems associated with packaging for a machine of this speed is the transmission of signals between various points in the machine. Since the signals in this machine will have wavefronts that must rise in about 20 milli-microseconds, these signals will contain appreciable energy at frequencies of 100 megacycles and above. It is discouragingly easy to demonstrate that an open-wire transmission line will ring when it is pulsed with the type of signal mentioned previously. We, therefore, are giving serious thought to the use of coaxial lines for a large fraction of our back panel wiring. We hope that we will not have to use coaxial lines within pluggable units. In order to reduce cost and bulkiness, we plan to take a serious look at the advantages that etched wiring techniques have to offer in the fabrication of "coaxial" lines.

In Figure 1. (a) we have a center conductor running between two ground planes. These are attached to a phenolic or plastic card. The conductors can be formed either by the additive or subtractive process. Figure 1. (b) is another form of the "coaxial" line. The ground plane or conductors will permit most of the electric field lines from the center conductor to terminate on it rather than on other lines or grounds. Thus we have a coaxial line that has been flattened out and made adaptable to modern packaging techniques.

Another problem that is intimately associated with the packaging problem is the problem of noise on ground lines. It should be reasonably easy to maintain a ground line, within a pluggable unit, that is free from potential gradients. The possibility of maintaining a gradient free ground line for the complete machine looks very difficult. If it is not possible to maintain a gradient free ground line except within pluggable units, then the problem of power-supply tolerances must be looked at with care.

Large capacitors that are connected between the supply and ground on a pluggable unit will tend to minimize the magnitude of voltage excursions due to transient loading. In addition, the supply should be decoupled from the pluggable unit in order to prevent the supply voltage from fluctuating with the ground line. Resistors or inductors can be placed in series with the supply line for the purpose of decoupling. The resistor aggravates the regulation problem and the inductor may be unreliable unless it is hermetically sealed. An interesting possibility is shown in Figure 2.

It is seen that the silicon diodes are operated in their avalanche region. They, therefore, supply a constant voltage to a pluggable unit or to groups of pluggable units. The resistors that are in series with the plus and minus supply voltages limit the current to the diodes to somewhat more than the maximum current required by the circuits. The variational resistance of the silicon diode in the avalanche region is quite low. It turns out that silicon diodes with an avalanche breakdown of five volts have a zero temperature coefficient. This method of regulation has the attractive feature that the short-circuit current is limited to a predetermined value. If such silicon diodes can be made cheaply, this might prove to be an attractive method of providing regulated voltages with short-circuit protection.

We mentioned previously that it is possible to maintain gradient free ground lines within a pluggable unit or possibly within regions of a machine. Figure 3 shows two pluggable units or regions in a machine that have gradient free ground planes. The equivalent noise generators cause these ground planes to fluctuate in potential with respect to a reference ground plane and hence with respect to each other. The problem of transmitting signals from one region to another is a serious one if the difference in potential of their respective ground planes is different. It is then possible for noise to be added to the signal. In the past, we have tried to overcome this difficulty by adequate biasing which, in general, slows down a machine. It might be better to design most of the logic to operate with gradient free ground lines that are achievable within a pluggable unit or region of the machine. Connecting stages would then be used as shown in Figure 3, between pluggable units or regions with gradient free ground lines. A very simple example of such a connecting stage, that is limited to pulse type logic, is a pulse transformer. It has the virtue of being able to transmit the signal or differential mode and to reject the noise or common mode. It has the additional virtue of changing impedance level.

Transistor Circuits

A. Draft Transistor:

It is not possible in the time available to go into any detail concerning our circuit development effort. As mentioned previously, we are expecting to achieve rise and fall times equal to or less than 20 milli-microseconds under loaded conditions. Naturally, we need a high-speed transistor in order to attain this speed.

Our circuit development is based on the drift transistor. The most important physical feature of the drift transistor is that the resistivity of the base region is very low at the emitter and relatively high at the collector. This produces several desirable effects from the circuitman's point of view. One of the most important advantages that this graded base type of construction offers is the fact that it greatly increases the alpha cut off frequency of the transistor, for a given base thickness.

Equally as important is the fact that it provides a low equivalent base resistance and it somewhat facilitates the achievement of a low collector capacitance. The alpha cutoff frequency that is presently being achieved is in the hundreds of megacycles range. The alpha cutoff frequency of a transistor is comparable to the frequency in vacuum tubes at which one is bothered by transit time difficulties. Most vacuum tubes begin to exhibit transit time troubles at about one hundred megacycles. If this is the case, one might justifiably ask why we expect to be able to operate a transistorized machine at many times the speed of a vacuum tube machine. The answer lies in the fact that the transistor operates with a much smaller signal swing than does the vacuum tube. This means that there is much less energy stored on stray capacitance. In addition, the stray capacitance is much smaller because of the smaller size of the components in a transistorized machine.

B. Reliability:

Another important advantage that the transistor offers is reliability. We are very confident that the transistor will permit us to achieve a degree of reliability that is unachievable with vacuum tubes.

This comes about in several ways: first, the transistor, if used properly, has a greater useful life than the vacuum tube; second, the transistor is theoretically free of catastrophic failures; and third, the other components such as resistors and capacitors are operated at low voltage and power ratings. All of these factors are important in achieving maximum reliability.

C. Marginal Checking:

Because of the freedom from catastrophic failures which the transistor offers, marginal checking becomes a very powerful tool. We plan to make marginal checking considerations a fundamental part of the circuit development and, later, the detailed circuit design. We feel that the problem of marginal checking must also be given consideration by the logic and packaging people.

D. PNP and NPN Transistors:

We are looking with anticipation at what the physical research and component research people can provide for us in the way of complementary transistors. They are presently providing us with reasonably good PNP drift transistors. We feel that the availability of NPN transistors with characteristics that match their PNP counterpart would enable us to achieve our goal with less stringent specifications imposed on the transistor.

E. Specifications:

The specification of the transistor is an extremely important task in view of the fact that any transistor that IBM makes either meets the specification and is used or does not meet it and is discarded. A relative minor change in the specification, therefore, can produce a very large amount of scrap. The only way that a realistic set of specifications can be achieved is by very close teamwork between the circuit design, device development, and manufacturing people.

F. Circuit Simulation:

One way in which we can simplify the problem of transistor specification and at the same time improve circuit performance and reliability and shorten device and circuit development time is by means of simulation. For quite some time, we have thought of a Utopia in which each transistor had about ten knobs projecting out of it that controlled such things as alpha, alpha cut off frequency, Cc, etc. The circuit designer would then be able to adjust the knobs until he had a transistor that the device man had not been able to produce. He would then plug it into his circuit and determine whether he should or should not encourage the device man to develop the device. On the other hand, he might choose to make up a transistor with one or more parameters at end of life in order to investigate the marginal characteristics of a circuit. We are now engaged in producing such a transistor by means of our circuit simulation effort.

Our circuit simulation effort has three phases. Phase one is concerned with getting an accurate mathematical representation for the transistor. This will include important non-linearities, delays, resistive and reactive components, etc. This phase is tied in very closely with the device people and their simulation effort. It will draw heavily on information obtained by measurements made on the transistor and on complete circuits.

Phase two will incorporate the mathematical representation for the transistor in circuits to be evaluated. In effect, a program for use on the 704 will be written for each of the circuits to be evaluated. This will enable the 704 to calculate the response of the circuit to an arbitrary input function. Provisions will be made so that the parameters of components may be varied in order that marginal conditions may be determined.

Phase three is directed toward permitting us to take the results of phase two to simulate small data-flow models. To do this, we feel that it will be possible to write a program for the 704 which will, in effect, use as subprograms the programs determined in phase two. Several people within the Military Products Division have agreed to take over the responsibility of this phase of the work.

Their co-operation is very much appreciated because in addition to speeding up the job, it minimizes the possibility of wandering down a blind alley since certain aspects of phase three can definitely influence the approach taken in phase two.

We feel that this simulation effort will have many advantages. One of these is the fact that it should be relatively easy for the circuit people to determine how much it would hurt or help them if a particular specification was modified in order to improve the transistor yield at the plant. Since the device people are participating in a similar effort, they will be in a position to give the circuit people a paper design of a transistor. This can be simulated in a small data-flow model by means of the 704. The device people can be told rather quickly whether the characteristics of this hypothetical model are desirable or how they should be modified. This should save many man hours of highly skilled people.

Much of the information learned as a result of the circuit simulation effort will be extremely useful, probably on a quantized basis, in the work on automation of design which Mr. Snyder discusses in his section on Automation of Design.

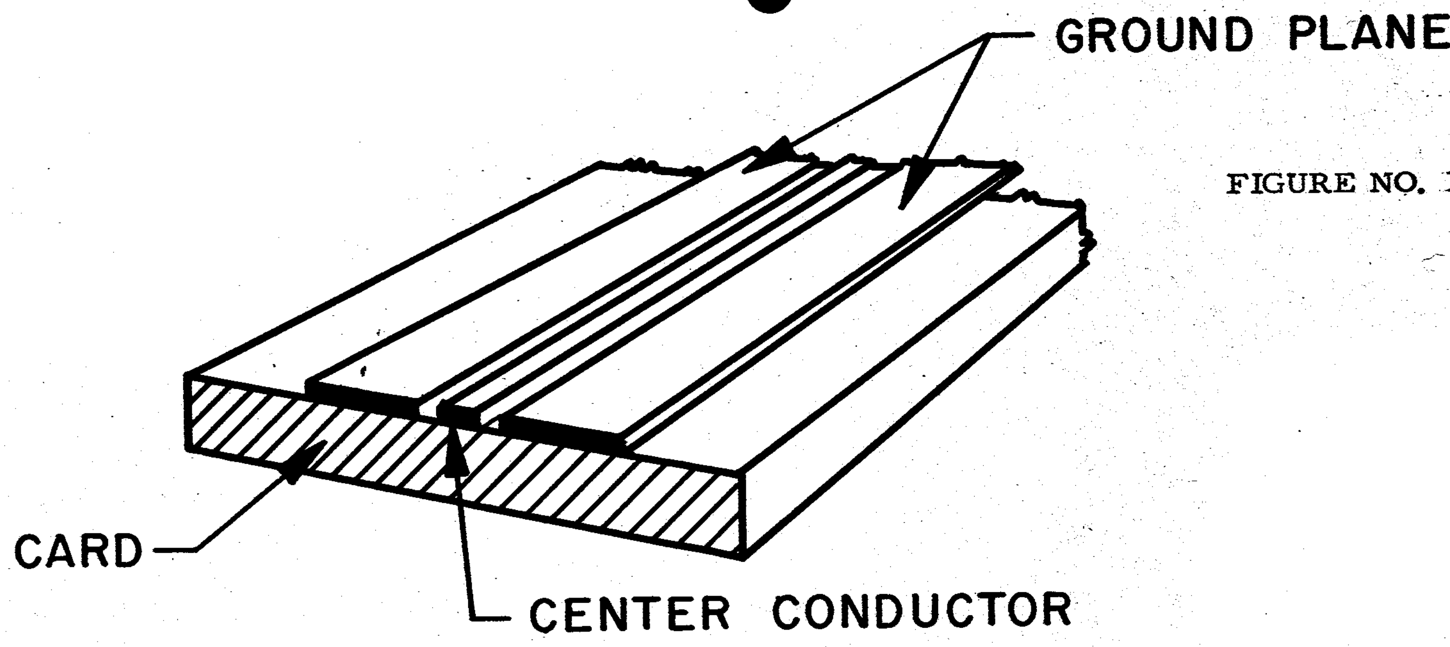


FIGURE NO. 1A

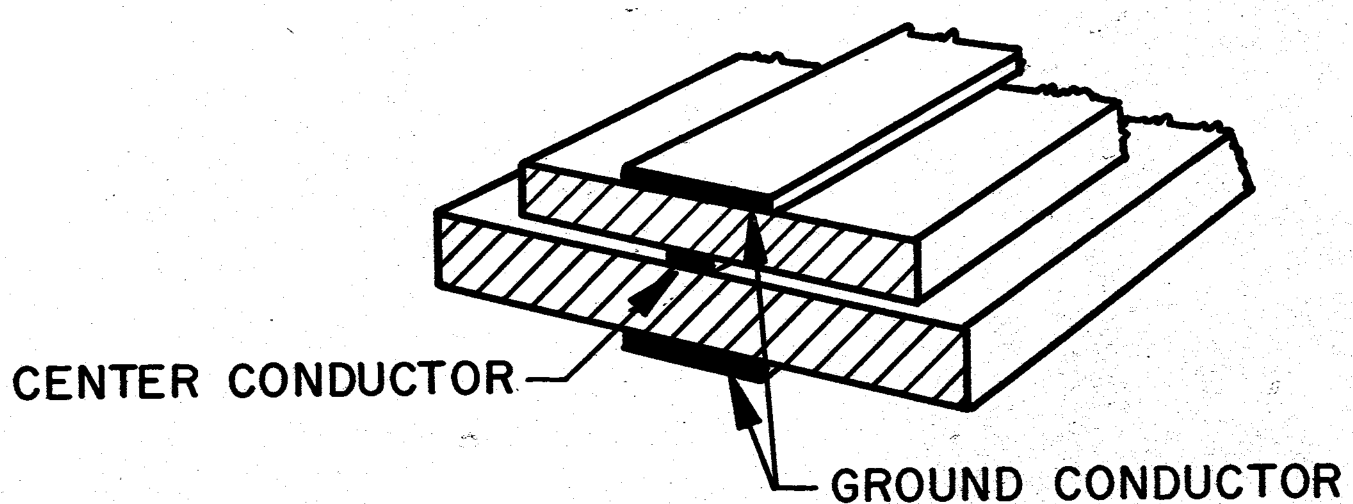
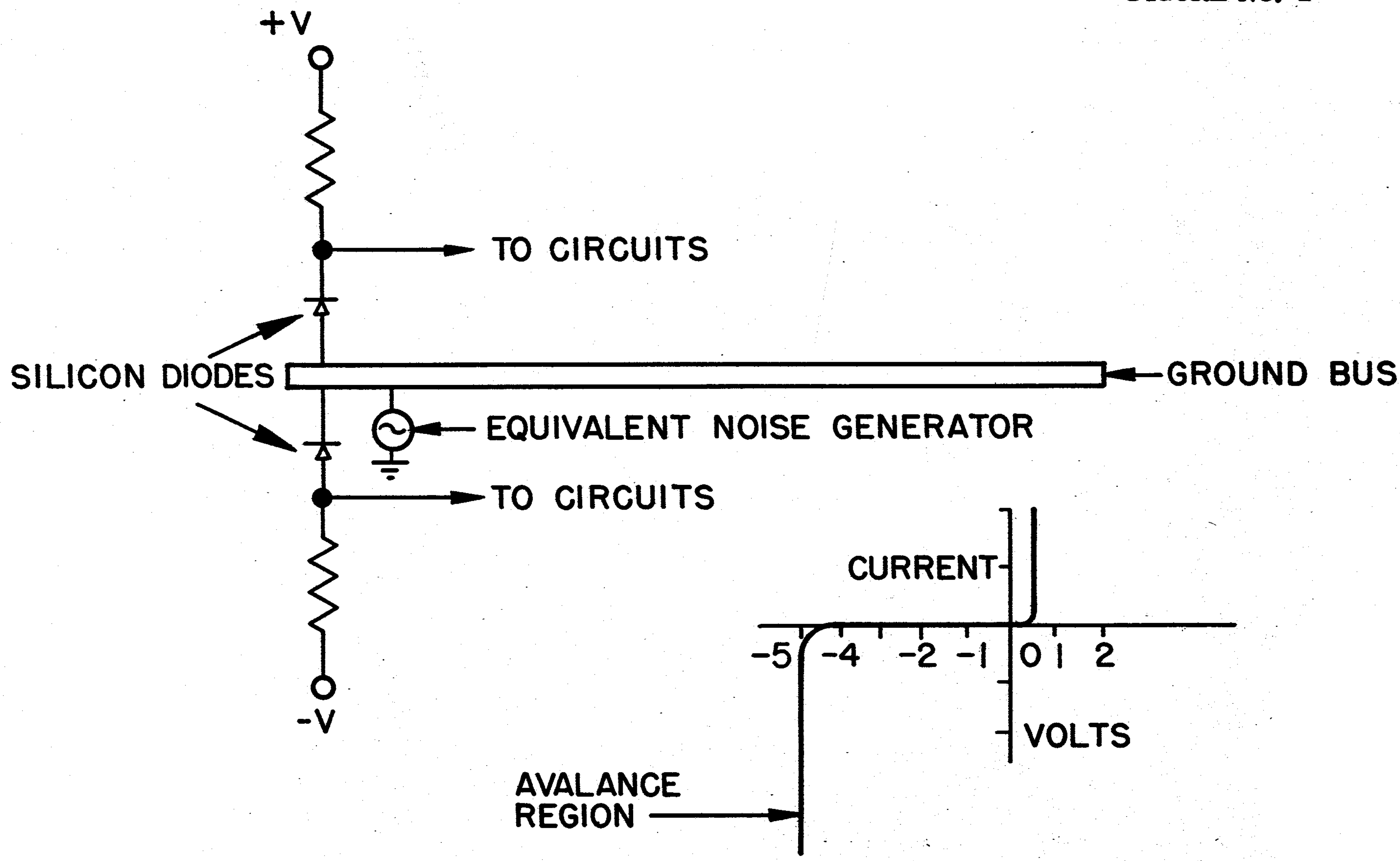


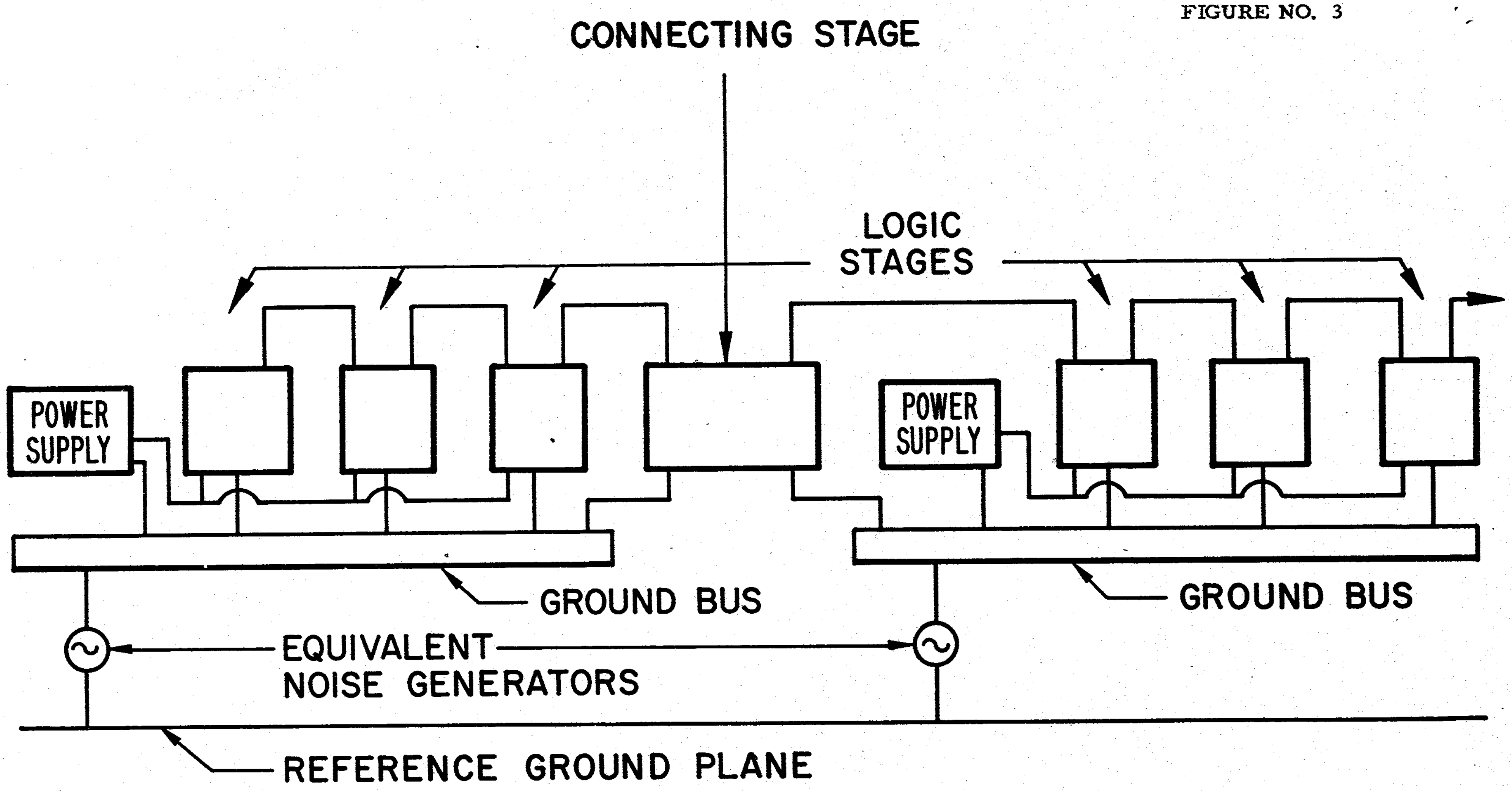
FIGURE NO. 1B

COAXIAL LINES THAT ARE ADAPTABLE TO ETCHED WIRING TECHNIQUES

Stretch Memo No. 39E



USE OF SILICON DIODES AS VOLTAGE REGULATORS



POWER SUPPLY AND NOISE CONSIDERATIONS