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SIGNAL DISTRIBUTION IN AUTOMATIC CHECKOUT SYSTEMS

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INTRODUCTION

This paper deals with several selected aspects of signal distribution in automatic checkout systems. These are:

1. The use of relay matrices as control elements
2. The inclusion of self-checking capabilities
3. Problems of systems integration

These aspects are not unique to automatic checkout systems. However, due to the nature of automatic checkout systems as presently being designed around digital circuitry, they find either fuller or different applications than in other types of systems. Also, while they are on the surface somewhat disconnected in nature, they tend to interrelate during the implementation of an automatic checkout system.

THE RELAY MATRIX AS A CONTROL ELEMENT

The use of a relay matrix as a switching device is not uncommon. It has, however, found more extensive use in data gathering systems as a form of multiplexer than in checkout systems as a control element. However, in a digitally controlled automatic checkout system it finds a very useful application. This usefulness is further enhanced by the fact that the matrix may be endowed with a memory capability through the use of latching type relays. This type of matrix has a direct application to the control of space vehicles during checkout and launch where the signals involved must be maintained in one of two states for long periods of time.

The relays within the matrix are generally controlled by solid-state switches driving appropriate voltages to create the necessary potential across the coils. In systems controlling space vehicles with their attendant cryogenics, hypergolics, and high pressure gas systems, the reliability of the control electronics operating the various valves and switching in the vehicle is a prime consideration. Of special importance is the requirement for a high degree of assurance that inadvertent signals are not sent to the vehicle. Several methods of gaining that high degree of assurance are available. The two most straightforward are 1) series contacts and 2) echo checking.

THE USE OF SERIES CONTACTS

The use of series contacts involves the operation of two relays in order to apply a signal to the vehicle. One relay provides control over a command bus which is then fed to several other relay contacts which apply power to the required command lines to the vehicle. The second relay is operated and its proper operation verified through monitoring a second set of its contacts. Once the proper operation of the actual command relay is verified, the first relay is energized to apply power to the command bus and thus to the vehicle. This approach to the problem has one serious drawback. In order to provide continuous signals as required for checkout systems, almost a one to one relationship between the number of series relays and the number of control relays must exist. While this does provide a large amount of protection against the inadvertent application of a control signal, it seriously reduces the actual operating reliability of the system and complicates the control signal generation process.

THE USE OF ECHO CHECKING

Echo checking is, as the name implies, the process of checking the signals being used to control the matrix relays as they are applied. In effect, the "echo" of the control signal is checking by the computer to ensure that the combination of control signals is correct. Consider a matrix having n x m coils, where n lines are driven at a voltage level V_1 and the m lines are driven at V_2 such that $V_1 - V_2$ is the operating voltage of the relay coils. If we assume that a standard crystal can relay, either magnetically latching or not as is appropriate to the control signal requirements, is used then this potential will be 28 VDC. In order to energize one of the coils in the matrix, one line in set n is driven to V_1 and one line in set m is driven to V_2. All other lines in sets n and m are kept "off". If, in addition to being wired into the matrix to the proper relay coils, all of the n and m lines are also connected to the discrete (bi-level) measuring circuits of the checkout system, the state of the control lines may be monitored by the computer controlling the operation at the same time that the relay itself is in the process of changing state.

The particular approach to the problem has several nice features. One is that the digital words brought back from the measuring portion of the system and compared to the proper form to check the operation of the control circuitry are in a different form usually than that digital word used to initiate the control operation. Secondly, once such a matrix and the associated control and measuring circuits have been checked out and are operating, any inadvertant signal will show up during the echo checking operation. If the data gathering system and computer are sufficiently fast with respect to the operating time of the relay, the echo checking may be accomplished while the relay is actually in the process of changing state. This means that if it is determined that an incorrect control signal is present, the operation may be stopped before the relay finishes changing state, thus preventing any inadvertant signal from appearing at the vehicle. As a result, even a shorted relay driver on one of the matrix control lines will not cause an inadvertant signal to be sent to the vehicle since the opposite polarity driver can be turned off prior to the relay changing state.

This final feature noted contains one pitfall, however, that must be avoided in order to achieve the results described. Care must be taken to differentiate between the operate time of the relay and the pulse duration necessary to cause them to operate. This is particularly important for latching relays. In general, the operate time of a crystal can relay is between two and four milliseconds at 28 VDC. However, the pulse duration required to cause a magnetically latching relay of the same type to change state is considerably less. This duration varies from relay to relay and for different operating voltages. Figure 1 shows the results of some recent tests along this line to determine the actual times involved.

S-IVB-1788

OPERATE TIMES FOR
MAGNETICALLY LATCHING RELAYS

RELAY USED - P/N 2LP-8-63
NUMBER OF RELAYS TESTED - 41

*PULSE LENGTH REQUIRED FOR CONTACT CLOSURE (MILLISECONDS)	MIN.	1.18	1.05	0.88
	AVE.	1.60	1.36	1.15
	MAX.	1.90	1.58	1.34
ACTUATION TIME (MILLISECONDS)	MIN.	1.90	1.75	1.60
	AVE.	2.23	2.00	1.80
	MAX.	2.51	2.30	2.01

*NOTE - THE TIME REQUIRED TO BREAK A NORMALLY CLOSED SET OF CONTACTS IS APPROXIMATELY 0.2 MILLISECONDS FASTER.

THESE TESTS WERE PREPARED BY R. O. KARLI ON 6/8/64
AT DOUGLAS SPACE SYSTEMS CENTER, HUNTINGTON BEACH

FIGURE 1

THE INCLUSION OF SELF-CHECKING CAPABILITIES

A system used for the checkout of space vehicles has a two-fold mission. Firstly, it must operate the vehicle in a manner which demonstrates that the vehicle meets its design requirements and that it will operate under those conditions which will be imposed upon it. Secondly, the checkout system must locate any faults within the vehicle which may prevent its operation as indicated.

One of the main arguments for changing from manual to automatic checkout systems is the reduction of schedule problems involved in checkout. Particularly in an R&D program, the time required to complete the checkout of a vehicle is a highly variable parameter. The use of automatic checkout equipment should both reduce and make more consistent this time required.

The actual operating time of the vehicle during checkout is generally not a function of the checkout system. In fact, the system must provide the capability of sequencing the vehicle in real time to provide simulated flight conditions. However, the time to isolate a fault to a replaceable unit and replace that item such that the checkout may continue is highly variable and contributes greatly to the wide fluctuations in checkout times. It is obvious, therefore, that if the automatic system is to provide schedule advantages, it must provide a high order of capability in the area of fault isolation. Fortunately, this is a function for which automatic systems are ideally suited. In fact, the amount and speed of fault isolation is only limited by the vehicle design, the amount of effort spent preprogramming fault isolation routines, and the reliability of the checkout system.

Requirements are imposed on the vehicle in three levels of priority. In decreasing order these are:

1. Those required to meet the flight performance specifications.
2. Those required to telemeter flight performance for post-flight evaluation.
3. Those required to allow checkout of the vehicle prior to launch including factory checkout and acceptance firing.

In many cases the requirements of acceptance firing may individually take a higher priority than the general class. However, in general those things which could be incorporated in the vehicle in order to expedite checkout must be evaluated against the higher priority requirements including such considerations as weight, size, flight reliability, etc. As a result, it is generally the case that the checkout designer exerts a relatively small amount of influence on the vehicle design.

Secondly, it is obvious that time must be spent preprogramming fault isolation routines. The completeness of this effort is primarily a function of manpower and schedule availability for such efforts.

Therefore, the checkout system designer should primarily concern himself with the reliability of the checkout system itself since that is the area in which he can exert the most influence over the total program success. Probably the two most overly used and multiple defined terms used in engineering today are "reliability" and "systems". Hence, in order to concern himself with the reliability of the checkout system, the designer must first define what a reliable system is. A reliable system has three main attributes. These are:

1. The checkout system can be checked out and ready to operate at the time that the vehicle is ready to be tested.
2. The checkout system will locate and indicate those faults which exist in the vehicle and will not indicate faults that do not exist.
3. The checkout system will not contribute an unreasonable proportion of the down time experienced during the checkout operation.

The first attribute requires that the checkout system can be checked out in a period of time which is short relative to the time during which it is being used with the vehicle under test. It also implies that it can be checked out in such a manner that its operational readiness can be demonstrated to the satisfaction of those personnel responsible for the overall program. Therefore, the self-check capability designed into the system must be such that it can be exercised with little or no setup time and it must be sufficient to demonstrate the operational status of the system.

The second attribute requires that the checkout system be able to make use of the information which is accessible from the vehicle to determine and isolate faults. It must further have the capability of isolating faults between the vehicle and checkout system. This aspect is particularly important from the point of view of preventing the indication of faults in the vehicle which are in fact a result of a failure in the checkout system.

The final attribute requires that the system have a low failure rate during the operation. However, of even more importance than the failure rate is the time generally referred to as the meantime to repair. It is of little value to have a checkout system that will find and isolate any fault to a replaceable unit in the vehicle in minutes if the time required to isolate and repair faults in the checkout system is in hours. Stated simply, the time required for fault isolation and repair of the checkout system should not exceed the same order of magnitude as the equivalent time required for a vehicle fault.

On the opposite side of the coin, it is possible to insert so much self-check hardware in series with the operating hardware that the reliability of the total system goes down due to the increased complexity. At the same time, a large amount of self-check hardware soon prevents the problem of what is going to check the self-check hardware, etc. It is obvious that some compromise must be reached in the inclusion of self-check circuitry in the system.

Self-check circuitry generally falls into two categories. These are:

1. That which is used on-line as part of the operation.
2. That which is used off-line solely for the purpose of self-checking the checkout system.

Obviously, most of the hardware that is used for on-line purposes is also usable off-line. Several examples of each type of self-checking techniques are shown in Figures 2 and 3. A detailed description of these various techniques is not within the scope of this paper. However, several general tules for their application may be formulated. These are:

1. On-line self-checking operations should be such that the time required to process the self-checking information does not reduce the capability of the checkout system to operate at the speed required to fulfill the mission of operating the stage in real time.
2. On-line self-checking circuitry should be in parallel with the operating circuitry whenever possible.
3. Off-line self-checking circuitry should never be in series with the operating circuitry.
4. Off-line self-checking circuitry should require a minimum setup, and leave intact as much of

S-IVB-1789

ON-LINE SELF-CHECK TECHNIQUES

1. PARITY CHECKING
2. ECHO CHECKING
3. DOUBLE TRANSMISSION METHODS
4. PERIODIC CALIBRATION SIGNAL INPUTS TO MEASURING SYSTEMS
5. DIGITAL RECORDERS WHICH MONITOR THE OPERATION OF THE CHECKOUT SYSTEM AND INTERRUPT ITS OPERATION IN THE EVENT OF A STATUS OF EVENTS WHICH HAS BEEN DEFINED AS IMPROPER

FIGURE 2

S-IVB-1790

OFF-LINE SELF-CHECK TECHNIQUES

1. SIMULATORS, BOTH ELECTRICAL AND ELECTRO-MECHANICAL
2. SIGNAL GENERATORS
3. SPECIAL MAGNETIC TAPES WITH KNOWN SIGNALS RECORDED THEREON
4. BLIND PLUGS TO FEED SIGNALS BACK INTO THE SYSTEM WITH A KNOWN FUNCTIONAL RELATIONSHIP WITH OUTPUTS OF THE SYSTEM
5. INCLUSION IN OPERATING ITEMS OF A MANUAL MODE TO ALLOW CHECKOUT OF THAT ITEM INDEPENDENT OF THE REST OF THE SYSTEM
6. GENERATION OF SPECIAL PROGRAMS USING PRIMARILY THE ON-LINE SELF-CHECK CIRCUITRY TO VERIFY SYSTEM OPERATION

FIGURE 3

system as possible. The ideal situation is one in which the only connections required replace those normally going to the vehicle under test.

5. In all cases, each self-check circuit included should be evaluated to ensure that it is contributing to at least one of the system attributes noted for reliable systems and that its inclusion does not reduce any others.

PROBLEMS OF SYSTEM INTEGRATION

System integration for relatively large automatic checkout systems is a complex operation. The goal of such an operation is to convert a large number of end items (such as computers, interface units, distribution units, signal conditioning units, etc.) into an operational entity which is capable of accomplishing the required missions of the checkout system. In many cases formal areas are set aside near the end of the production line where "integration" takes place prior to shipment to the using area. In other cases, this operation takes place on site after the installation. In either event, the result is usually a set of "make-work" fixes, changes in operating procedures, and in some cases the abandonment of certain secondary capabilities which can be eliminated without serious degradation to the overall operation.

From the aspects of schedules, systems integration is a frightening operation. The time required to integrate a checkout system is extremely difficult to predict. Nor is it constant from site to site even though the hardware may remain the same. Since the time allotted for system integration is that time from the delivery of hardware to the required use date, and since hardware delivery dates are prone to slip for a multitude of reasons, the time required for the integration of a checkout system is partially defined by the time available. Obviously, the reliability of the system once it is put into use is partially a function of the thoroughness of integration and checkout prior to its use. Therefore, the program scheduler is faced with a systems integration operation of indeterminant duration which must take place from a hardware delivery date that is late to a required use date that seems all too soon.

There is, however, one consistency with respect to the time required for systems integration. That is that the time required to get a system "on the air" is inversely proportional to the amount of work and preparation put into this effort prior to hardware delivery. Further, this relationship is not necessarily a linear one. In general, if a small number of problems are encountered during systems integration, they can be readily found and solved since the situation is not clouded by a multiplicity of problems. On the other hand, if a great many interface and design problems exist at the same time, the symptoms may appear inconsistent with the basic problem since it is clouded by non-associated, but interfering problems. Therefore, the goal of the pre-delivery systems integration effort is to solve as many of the expected problems as possible such that when the hardware is delivered and installed the problems remaining are small in number and can be attacked directly, and not through a large number of extraneous problems.

THE EFFECTS OF A MODULARITY

In the last ten years space vehicles have been increasing in size and complexity while the requirement for in-flight reliability has been becoming more and more important. As a result, checkout systems have become increasingly large and complex. Adding to this complexity of checkout systems is an increasing requirement for versatility. This versatility is required for two main reasons. These are:

1. Vehicle schedules are usually in parallel with or slightly lagging checkout system schedules in the early parts of the program.
2. Changes are made to the vehicle after manufacture and before launch which must be accounted for in the checkout system.[1]

This requirement for versatility has resulted in the emergence of modularity as one of the primary characteristics of a large checkout system.

One of the better arguments for the use of a general purpose digital computer as the controlling element of a checkout system is its functional modularity. The computer will do precisely what it is programmed to do, and, at least in theory, the programming is a very flexible tool with a fast change time. This means that the system designer may vary the controlling element of the checkout system easily and quickly merely by changing the computer program. This has probably worked better in theory than in practice in the past, but advanced programming methods now being developed and tested show definite signs of making such flexibility a reality in the near future. With these advances in computer usage, the spotlight has been turned to the distribution systems which interface the controlling element with the unit under test. This requirement for flexibility has led to the growth of modularity and the usage of patch panels to interconnect these modules.

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[1] As an example, it was reported in a recent survey done by Rand Corporation for NASA that there were 3100 modifications and "reworks" to the SA-1 (First Saturn stage launched) after manufacture and before shipment to the launch area. While it is not claimed that all of these would cause a change in the checkout system, 10% effectivity would probably not be unreasonable. Even this number is considerable. See Growth of Automation in Apollo Prelaunch Checkout, Go/No-Go Testing, Vol. I, July 1964 - by L. T. Mast, L. D. Amdahl, O. T. Gatto, and A. A. B. Pritsker.

As a result of this modular characteristic being built into the distribution system, the problems of integrating such a system becomes partly one of tying together the modules in a manner that will accomplish the system mission. This is generally accomplished in three major areas of interface. These are:

1. Cable interface
2. Patching instructions
3. Test program dictionary definition

The effort expended in these areas to define and ensure the interfaces of end item to end time, module to module, and hardware to software, comprises a large portion of the systems integration process. In fact, if the above interfaces are accurately defined and implemented, the problems of systems integration become largely those of noise suppression and design evaluation.

CABLE INTERFACE

A present day automatic checkout system has on the order of twenty to forty end items which are interconnected by a cable network of from three to six hundred cables. This network may represent on the order of 20,000 conductors. It is obvious that some care is necessary to ensure that the same function is defined for a given conductor at both ends of the cable. While this may appear at first glance as a trivial problem, when the number of conductors reaches the size indicated and the number of engineers involved in end item design is in the hundreds, the problem loses its triviality.

Figures 4 and 5 represent a technique for coordinating pin assignments between end items in such a way that there is little room left for misunderstanding. Each cable in the network is represented by a sheet as shown. Pin assignments are made in detail and the sheets distributed to each of the end item engineers involved. When a set of sheets representing every connector on the end item has been delivered to the responsible end item engineer, his cable interface is clearly defined. Any changes during the progression of the design are recorded on revised sheets and redistributed.

In addition to assigning functions to specific pins, these sheets have several other uses. As can be seen in figure 4, this cable represents thirteen twisted shielded pairs, each containing an analog function. One end of the cable goes to a response signal conditioner unit as indicated at the top left. The other end goes to an analog patch panel as indicated at the top right. Connector insert configurations are defined for each as are reference numbers for plug identification. Also the plug mold configuration (straight or angled as indicated) is defined. Therefore, the only information missing that is necessary to define all requirements for cable design and fabrication is an equpment layout to define cable length requirements. This layout is generally available quite early in the program.

It should also be noted that each of the analog signals defined in figure 4 have a code number assigned. This code number can be used to represent this channel of the response signal conditioning unit for the purposes of patching analog signals in the analog patch panel. Thus, this sheet also defines the location of individual response signal conditioner channels in the patch panel once the relationship between input connects and the patch board is defined.

Finally, if the code numbers assigned the various channels in the system are related to the actual digital word used to acquire that channel, the information contained on these sheets helps to define the hardware/software relationships. In the case shown, the three digits represent an octal number which is directly related to the digital address sent to the response conditioning unit to

RESPONSE SIGNAL CONDITIONER – ANALOG PATCH PANEL
461 J1 TO 476A2 J1

CABLE INSERT 20-39 S — ST ☒ 90° ☐ 45° ☐
CABLE INSERT 20-39 P — ST ☒ 90° ☐ 45° ☐

PIN	FUNCTION	PIN	FUNCTION
A	0-5 Volt Analog A401 Return	X	SHIELD
B	A401 Signal	Y	0-5 Volt Analog A410 Return
C	SHIELD	Z	A410 Signal
D	A402 Return	a	SHIELD
E	A402 Signal	b	A411 Return
F	SHIELD	c	A411 Signal
G	A403 Return	d	SHIELD
H	A403 Signal	e	A412 Return
J	SHIELD	f	A412 Signal
K	A404 Return	g	SHIELD
L	A404 Signal	h	A413 Return
M	SHIELD	i	A413 Signal
N	A405 Return	j	SHIELD
P	A405 Signal	k	A414 Return
R	SHIELD	m	A414 Signal
S	A406 Return	n	SHIELD
T	A406 Signal	p	A415 Return
U	SHIELD	q	A415 Signal
V	A407 Return	r	SHIELD
W	A407 Signal		

FIGURE 4

ELECTRICAL NETWORKS CONSOLE – BI-LEVEL PATCH PANEL
487 J1 TO 476A1A1 J26

CABLE INSERT 24-61 P — ST ☒ 90° ☐ 45° ☐
CABLE INSERT 24-61 S — ST ☒ 90° ☐ 45° ☐

PIN	FUNCTION	PIN	FUNCTION	PIN	FUNCTION
A	AFT BUS 2 OFF (S5-1)	X	SEQ PWR OFF (S18-1)	t	FWD BUS 1 & 2 INTERNAL (DS8A)
B	AFT BUS 2 ON (S5-3)	Y	SEQ PWR ON (S18-3)	u	FWD BUS 1 & 2 EXTERNAL (DS8B)
C	AFT BUS 1 OFF (S6-1)	Z	SPARE (S13-1)	v	MAN CONT ACTING (DS9A)
D	AFT BUS 1 ON (S6-3)	a	SPARE (S13-1)	w	ENABLED (DS9B)
E	BATT SIMULATE OFF (S7-1)	b	SPARE (S14-1)	x	MAN CONT DISABLED (DS9C)
F	BATT SIMULATE ON (S7-3)	c	SPARE (S14-3)	y	RF SILENCE ON (DS10)
G	FWD BUS 2 OFF (S8-1)	d	SPARE (S15-1)	z	DDAS SYS PWR ON (DS14)
H	FWD BUS 2 ON (S8-3)	e	SPARE (S15-3)	AA	T/B PWR ON (DS15)
J	FWD BUS 1 OFF (S9-1)	f	FWD TO INT (S20-3)	BB	SEQ PWR ON (DS16)
K	FWD BUS 1 ON (S9-3)	g	NOT USED	CC	SPARE (DS11)
L	AFT 1 TO EXTERNAL (S10-1)	h	NOT USED	DD	SPARE (DS12)
M	AFT 1 TO INTERNAL (S10-3)	i	AFT BUS 2 ON (SD1)	EE	SPARE (DS13)
N	MAN CONT OFF (S11-1)	j	AFT BUS 1 ON (DS2)	FF	MAN CONT ACT (S11-6)
P	MAN CONT ACTIVATE (S11-3)	k	BATT SIMULATE ON (DS3)	GG	AFT 2 TO EXT (S19-1)
R	RF SILENCE OFF (S12-1)	m	FWD BUS 2 ON (DS4)	HH	AFT 2 TO INT (S19-3)
S	RF SILENCE ON (S12-3)	n	FWD BUS 1 ON (DS5)	JJ	FWD TO EXT (S20-1)
T	DDAS PWR OFF (S16-1)	p	AFT BUS 2 INTERNAL (DS6A)	KK	NOT USED
U	DDAS PWR ON (S16-3)	q	AFT BUS 2 EXTERNAL (DS6B)	LL	NOT USED
V	T/B PWR OFF (S17-1)	r	AFT BUS 1 INTERNAL (DS7A)	MM	NOT USED
W	T/B PWR ON (S17-3)	s	AFT BUS 1 EXTERNAL (DS7B)	NN	
				PP	NOT USED

FIGURE 5

access that channel of information. Therefore, the initial groundwork is laid for the generation of the test program dictionary.

Therefore, it can be seen that the preparation of sheets as shown in figures 4 and 5 early in the program provide the basis for all phases of system integration. The cable and cable interface is defined, a basis is provided for patching together the various modules of the system, and a link is provided between the hardware and software.

PATCHING INSTRUCTIONS

The growth of modularity in checkout systems has been accompanied by a growth of the number of patch panels. The patch panels are generally boards having two portions, a fixed board and a removable board. The fixed board is hardwired to the output connectors. The removable boards are those which have the patch cords installed and provide the actual interconnections. The boards vary in size form 800 holes to 4800 holes. The patch cords come in various forms from double ended to multiple cords allowing the interconnection of a number of points on the board with one cord.

These boards, due to the fact that the removable portion is relatively easy to change, provide a high degree of flexibility within the checkout system. The modular parts of the system are connected to the patch panels through the cable network, as is the unit under test. At that point the responses from the unit under test may be routed to appropriate signal conditioning, and the system control elements are connected to the appropriate command lines to the unit under test. At the same time signals may be accessed at the same patch panel for recording purposes and for special handling of critical items.

It should be obvious at this point that a large proportion of the systems integration effort is bound up in the patching instructions for the type of modular system being considered. Therefore, expedient techniques are necessary to create these patching instructions. A system of the size being considered may have as many as ten or twelve different patch panels in the system at various points. This number of boards results in approximately 30,000 patch points to be documented in patching instructions. As in the case of the cable interface, the magnitude of the effort required is the biggest problem to overcome.

Fortunately, many techniques have been evolved for the mechanization of wiring in the industry. Many computer programs have been written to provide documentation for wiring instructions in end items such as computer, etc. These techniques are also applicable to the generation of patching instructions. In addition, the modular characteristics of each a checkout system allows such a mechanization to actually perform many functions that would normally have to be performed by the engineer. If considerable care is taken early in the program such that the assignment of functions to connectors is done in such a way to ease the implementation of computerized definition of signal flow, and if the patch panels themselves are wired in such a way that there is a logical relationship between the input connectors and the patch points on the removable board, great advantage can be taken of the use of computers to generate patching information. It also follows that the patch panels themselves should be modular in nature to allow wide application of the same programs.

TEST PROGRAM DICTIONARY DEFINITION

The element of systems integration that probably takes place closest in time to the actual checkout operation is the definition of the test program dictionary. It should be obvious that this definition is largely a function of the patching configuration of the system since the patching instructions have defined which signals or commands are connected to which response channels or control elements. If sufficient information has been included in the patching programs discussed above (such as the digital codes shown in figure 4) it is possible that the computer programs utilized to generate the patching instructions can also be used to generate a large proportion of the test program dictionary. Such a capability, in addition to speeding up the process of dictionary generation, also eliminates many of the inconsistencies possible between hardware and software definitions of signal flow since the dictionary and the patching instructions are both being generated from the same information by the same program. Since dictionary generation is usually one of the last major integration efforts, the capability of quickly and accurately generating this interface definition is of extreme advantage in coping with both the magnitude and complexity of the checkout system as well as the expected vehicle changes during the checkout operation.

CONCLUSION

In attempting to discuss an area of the magnitude of distribution systems in automatic checkout systems in a single paper, the author has limited the discussion to only a few of the many aspects of the subject. Even these subjects have not been discussed to the depth to which they should be to completely understand the problems and techniques for solution. Secondly, to an experienced automatic checkout system designer (whatever that is) much of the foregoing may appear trivial, while to those engineers with little or no experience in that field the same information may appear obscure and confusing. It is hoped, however, that there are a sufficient number of engineers between the two limits noted to whom the information presented is neither. Similarly, it is hoped that the information presented herein will be used as a basis for more exhaustive studies and presentations of the prolems and solutions in this area of engineering.

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