X-207-70-475
PREPRINT

NASA TM X- 65417

FINAL TECHNICAL REPORT ON DIGITAL REALIZATION OF PULMONARY SCREENING AND MOTIVATING DEVICE

AUGUST 1970

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

X-207-70-475

FINAL TECHNICAL REPORT
ON
DIGITAL REALIZATION OF PULMONARY SCREENING AND MOTIVATING DEVICE

Israel F. Charo
Donald Gorelick

June 22 - August 28, 1970

H. Moffette Tharpe, Jr.
Technical Advisor
Information Processing Division

PRECEDING PAGE BLANK NOT FILMED

PREFACE

The technical results presented here represent a ten week effort by its authors during the Summer Institute for Biomedical Research sponsored by the Technology Utilization Office at the Goddard Space Flight Center. Their challenge was to apply NASA developed technology toward the solution of this particular problem and to demonstrate its usefulness to other problems in medical diagnostic monitoring instrumentation.

This report has been published and made available for general use so that others in both the technical and medical communities might benefit from the work of these individuals.

Wayne T. Chen, Coordinator
Summer Institute for Biomedical Research
Technology Utilization Office

PRECEDING PAGE BLANK NOT FILMED

CONTENTS

June 29, 1970

DIGITAL DEVICE

Statement of the Problem

The purpose of this effort is to improve the motivation and screening spirometer, by converting its analog output to digital form for computer analysis. At present it is necessary to manually adjust the reference voltage level of the comparators, through the use of prepared charts. We are to design a device with thumb switch inputs (age, sex, height), which will calculate using Kory's Regression Equations, the normal levels of Forced Expiratory Volume (FEV1); Peak Flow Rate (PFR); and Forced Vital Capacity (FVC) for a given individual.

July 1, 1970

New Statement of Problem

We met with Mark Wilbur at G.W. yesterday and discussed, to some length our problem. He has already designed and built an analog computer with thumb-wheel switch input to evaluate Kory's Regression equations. Our mission, should we decide to accept it, is to construct a digital equivalent to his device. The digital computer is necessary because of its higher accuracy, greater reliability, and greater repairability. The comparator circuitry can be either analog or digital. Mr. Wilbur has none of the hardware of his device available, so we may also construct the comparator, light driver and lighting circuitry.

July 24, 1970

We have been doing the computer computer logic design for the last two weeks. Many different ideas were thrown around and when we arrived at our "final" logic diagram we designed a timer circuit to perform operations in their correct order. Phone calls were made locating parts and information. We received some free samples from our Fairchild representative to serve as our parallel adder. We rounded up all the parts we will need, except switches. We got two Augat boards on which to build our breadboard model. We practiced the wire-wrap technique which we are going to use to construct our breadboard model.

The steps used in our computer (MIMI) to calculate FVC and FEV1 are:

1. Multiply 0.0176 x A
2. Add 2.88 to it

3. Store result
4. Multiply 0.1064 x H
5. Take 2's complement of (3)
6. Add (4) + (5) ignoring last carry
7. Store result in comparator flip flops
8. Clear registers
9. Follow same steps for FEV1
10. Store in other comparator flip flops

Kory's Equations

MALE	FVC	= 0.1065 x H -0.0176 x A -2.88 Liters
	FEV1	= 0.0752 x H -0.0224 x A -1.272 Liters
FEMALES	FVC	= 0.0833 x H -0.0144 x H -2.1512
	FEV1	= 0.0569 x H -0.0168 x A -0.6936

H = height in inches   A = age in years

PROBLEM: How to implement Kory's equations in binary form.

ANSWER: We have decided to multiply each equation by 1000. We therefore can multiply and subtract in the integer mode. The corresponding division by a 1000 will be done by adjusting the gain of the D/A or comparator circuit.

PROBLEM: How many bits should we use to get the accuracy required.

ANSWER: We decided to use G bits, which will give us an accuracy of about 1.5% which is "plenty good" considering the inherent inaccuracies of the test and other equipment. One estimate is that the test is 15% accurate.

PROBLEM: Using six bits to represent large numbers like 75.0

SOLUTION: Drop off least significant bit since it is less than 2% accurate anyway.

August 6, 1970

We have completed most of the wiring and mounted our 2 circuit boards as shown on page

We have constructed the panel of switches shown, which we use in conjunction with the light set to check our multiplier and subtractor. We have successfully made "MIMI" multiply! It must be remembered that the 6 least significant digits are not shown on the panel. We have noticed that when all switches in the top now are in the "1" position, the answer is larger than can be shown on the panel and does not remain constant. This has been our only problem with the multiplication thus far. We have not been able to include the schematic diagrams for the timing and logic circuits as they cannot fit on a sheet this size. Reproduction of this diagram has thus far also not been possible. Detailed entries are not possible now, as we are still wiring our calculator, and can only report the problems we encounter.

August 24, 1970

We have completed the major portion of work on the computer. It can now correctly evaluate Kory's equation, which is what we set out to do. We have already given our presentation of the project, and have successfully demonstrated it. Our major effort now will be directed towards documenting our work.

We discovered an effective way of checking to see what values are in our registers and adder, at a particular instant. We do this by setting the scope on EXTERNAL triggering, and using the timing pulse which clocks in our observed operation as the triggering pulse as well. In this manner, the scope will not show any signal, except when triggered by this one unique pulse. However, since the times we are dealing with are in 10-9 seconds, we get a continual trace. The method is superior to our previous one, of gating out the clock pulses following the one we were observing. This has the disadvantage of not having a free running clock, rather we are producing a static system. We cannot look at other clock pulses without a free running clock, so our troubleshooting ability was somewhat limited. Many times our erroneous answers were due to a failure in the timing circuit to generate the correct pulses at the proper time.

<u>Note on the adder</u> - We have used a 6 bit adder. This was constructed using three (3) Fairchild 9304 chips. Each chip is a 2 bit full adder.

We recommend that future versions of this computer be made at least 8 bits. This is due to our method of shifting in the multiplication cycle, and carrying through only the 6 most significant digits. We have also made this problem more serious by multiplying all of our coefficients by 1000 (10^3) before using them in the equations. This was done to avoid binary representation of decimal numbers. We therefore are actually dropping off bits that are significant and our machine should be an eight (8) bit device. This change should be made only after the 6 bit machine has been made operational and successfully integrated with the existing spirometry hardware.

We are having a problem with time. We find that we won't have time to complete wiring of the FEV1 equation, the six switch and make some changes which we feel will help the accuracy of our device. We feel it is necessary to document all the wiring we have done. The diagram is too large for the book so we are doing a large working drawing which may be blueprinted.

The switches for inputs of age and height must change a base 10 number from 0-99 to a binary number. We have thumbwheel switches which could be connected to a diode matrix to give us the correct binary representation. However, we don't have time to design the matrix. A switch which incorporates the matrix into its design can be bought from:

Digitran Company
855 S. Arroyo Parkway
Pasadena, California 91105
Phone: 213-449-3110 ATTENTION: Bob Nichols

Dual Binary Thumbwheel Switch - 3-D-173 Price $95.00

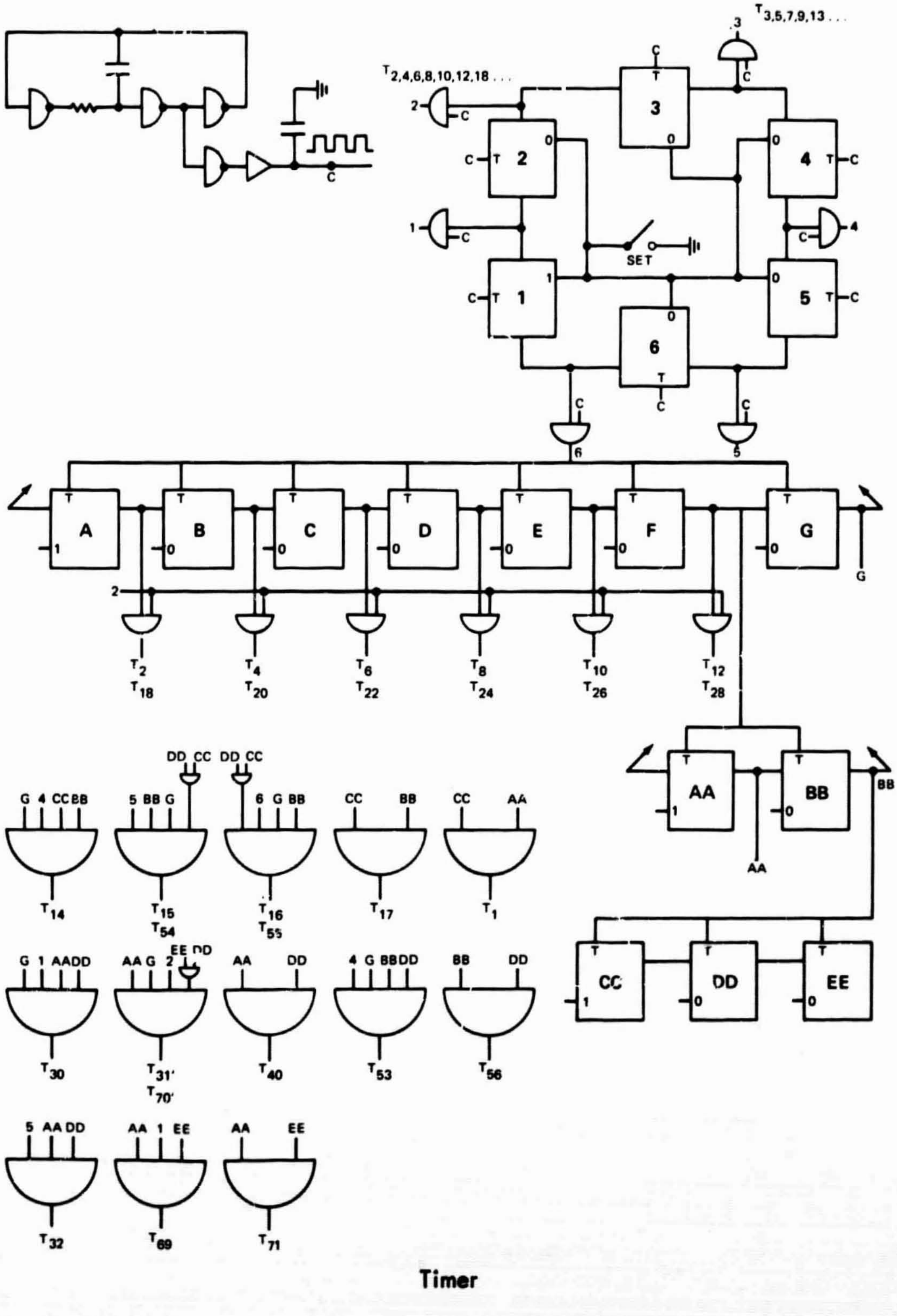
August 25, 1970

SUMMARY

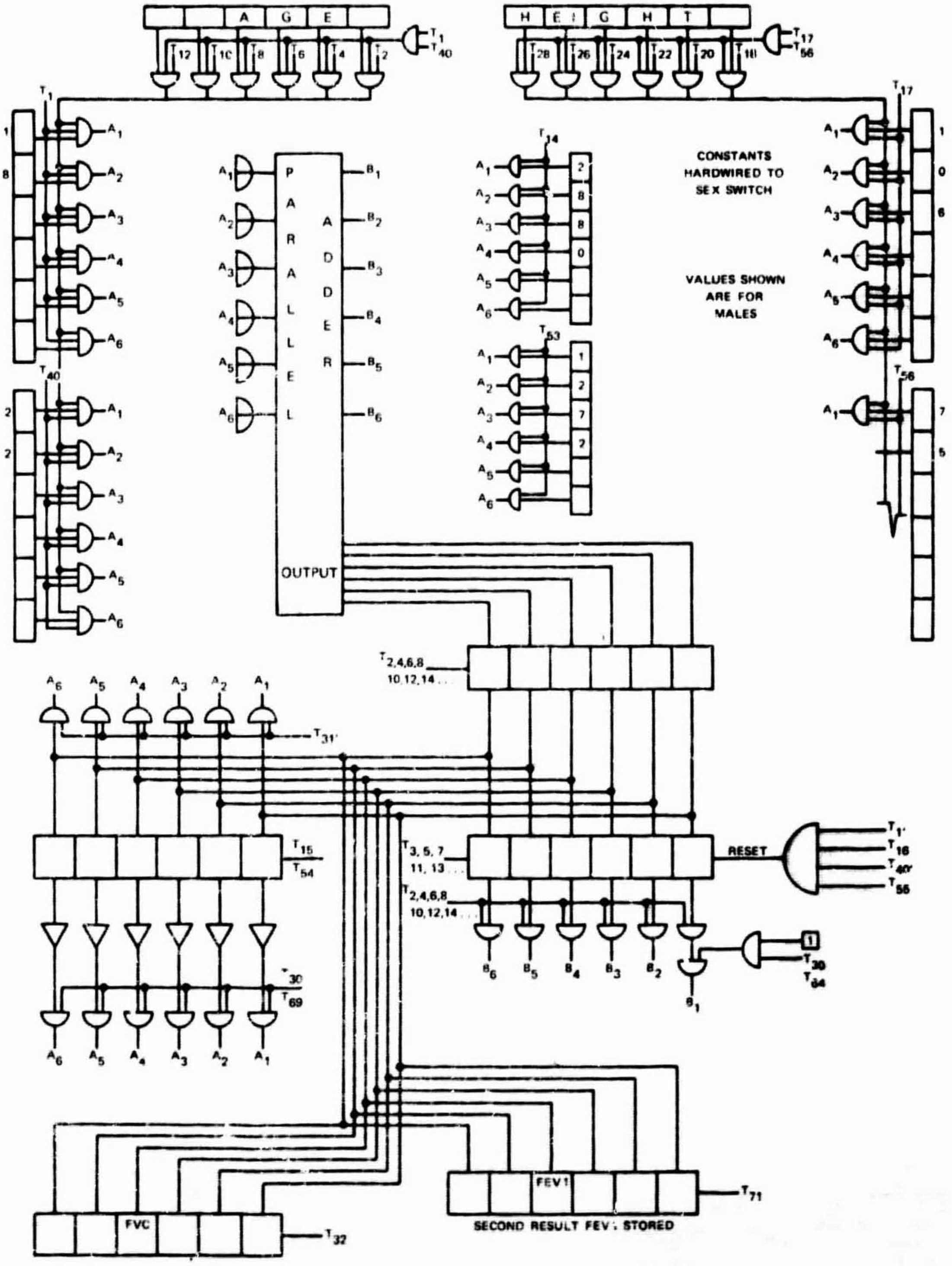
I will attempt to summarize our project to this point. We have made the computer correctly evaluate Kory's equation. The Kory Regression Module is now digitalized, which has the following advantages:

1. As accurate as desired (adding bits)
2. Not dependent on line voltage
3. Greater reliability
4. Easy to repair

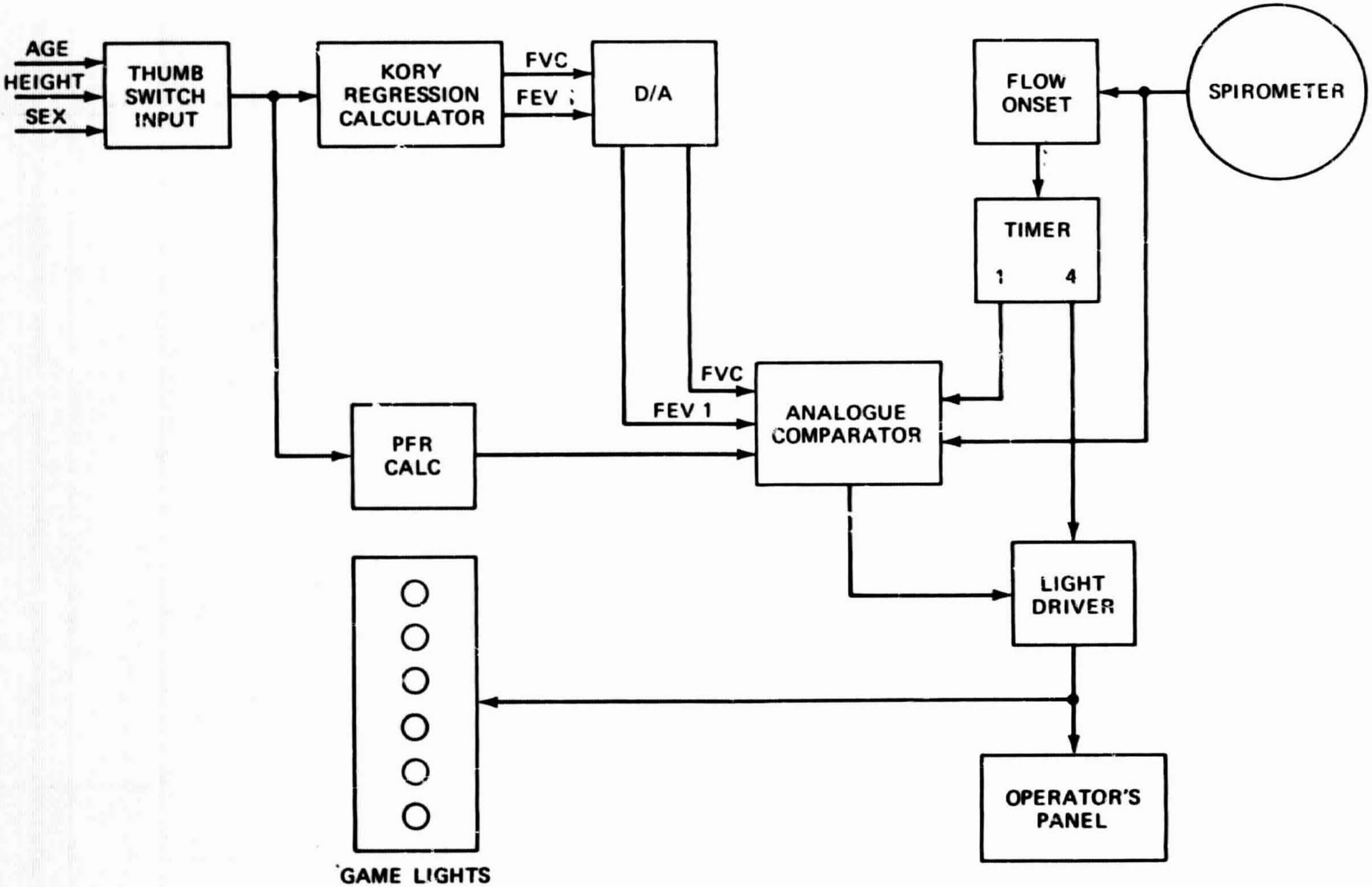
It now must be integrated with the existing spirometry electronics, which should not be difficult. All other items are commercially available.


SET
A
B
C
D
E
F
G
AA
BB
CC
DD
EE
T2 T18
T4 T20
T6 T22
T8 T24
T10 T26
T12 T28
T14
T15 T54
T16 T55
T17
T1
T30
T31' T70'
T40
T53
T56
T32
T69
T71

Timer



Basic Logic Design



Block Diagram of M.A.S.S.

Task V

DIGITAL REALIZATION OF PULMONARY SCREENING AND MOTIVATING DEVICE

COMMENTS

Methodology

No formal report was written for this project. Documentation of this task consisted of daily progress notes in a laboratory notebook. The flow of work, although not outlined on paper, is quite reasonable. As problems were encountered they were documented, along with appropriate discussion and conclusions. For example, how many bits (6 bits vs 10 bit circuits) should the calculations be resolved to get the required accuracy. This requirement was determined by the engineer's (students') reviewing the medical use and the range of values considered to be clincally significant in spirometric testing as contrasted to cost.

Results

The result of the project was a working breadboard model of digital logic design duplicating the concept of the motivation and screening spirometer. The breadboard model was constructed of digital logic components supplied by NASA and "debugged" in NASA's laboratories. "Flight line" components were used for the breadboard, but commercial grade logic circuits are available so that the cost would be considerably reduced.

Conclusion

It is interesting to note that after the actual prototype was built that some initial decisions should be changed. The students' remarks are as follows: "We recommend that future versions of this computer be made at least 8 bits. This is due to our method of shifting in the multiplication cycle, and carrying through only the 6 most significant digits. We have also made this problem more serious by multiplying all of our coefficients by 1000 (10^3) before using them in the equations. This was done to avoid binary representation of decimal numbers. We therefore are actually dropping off bits that are significant—and our machine should be an eight (8) bit device. This change should be made only after the 6 bit machine has been made operation(al) and successfully integrated with the existing spirometry hardware."

The students have done a formidable job in digital logic design, noting that neither student had experience in digital design. They have gained experience in the expansion of computers required by digital logic over analog devices, but have also noted the advantages of digital logic design:

"1. as accurate as desired (adding bits)

2. not dependent on line voltage

3. greater reliability

4. easy to repair"

Although the above are not sussinctly stated they do alude to some of the inherent advantages of a digital design.

Future Application/Expansion

Future application or expansion of the task is the application of the recent economic breakthrough of digital logic devices. This tends to make a small digital processing and motivation device for spirometry very reasonable to use in screening applications. The motivation portion should be implemented in the Multitest Facility of the George Washington University. However, present commitments and budget restricts immediate implementation.