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NASA CR 108132

Miniaturized Time Code Generator

Final Progress Report

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Northrop Corporation Electronics Division

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Miniaturized Time Code Generator

Final Progress Report

Prepared Under
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For

National Aeronautics and Space Administration
Flight Research Center
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1.0 SUMMARY

This final report covers the problems encountered and solved by Northrop Electronics in the design, development and production of a miniature Time Code Generator (NASA/FRC Contract No. NAS 4-1381). Recommendations for future units are also made. The system consists of a Time Code Generator and a Setting Control & Test Unit. This report contains photographs and specifications of the units described.

The Northrop Electronics miniature Time Code Generator, Part No. 50633500, is a high precision unit designed to provide at least one order of magnitude decrease in each size, weight and power over those presently available on the commercial or military market. The result is a unit about the size and weight of a deck of playing cards using wrist watch batteries, yet maintaining higher accuracy over the entire specified temperature range than some crystal controlled units. The unit produces a modified IRIG B serial time code in a modulated carrier form suitable for recording by magnetic tape recorders and other data recording or data analysis equipment. This information may be either real or elapsed time. Other formats can be easily provided. Power is provided by either internal batteries or external sources. The unit is protected at all times from damage from reasonable external malfunction, or errors.

The Time Code Generator is encapsulated in Stycast 1266, a hard, transparent, non-toxic epoxy, except for the batteries, which are sealed from the external environment by an o-ring. Access to the batteries is provided through a sealed, Lexan cover.

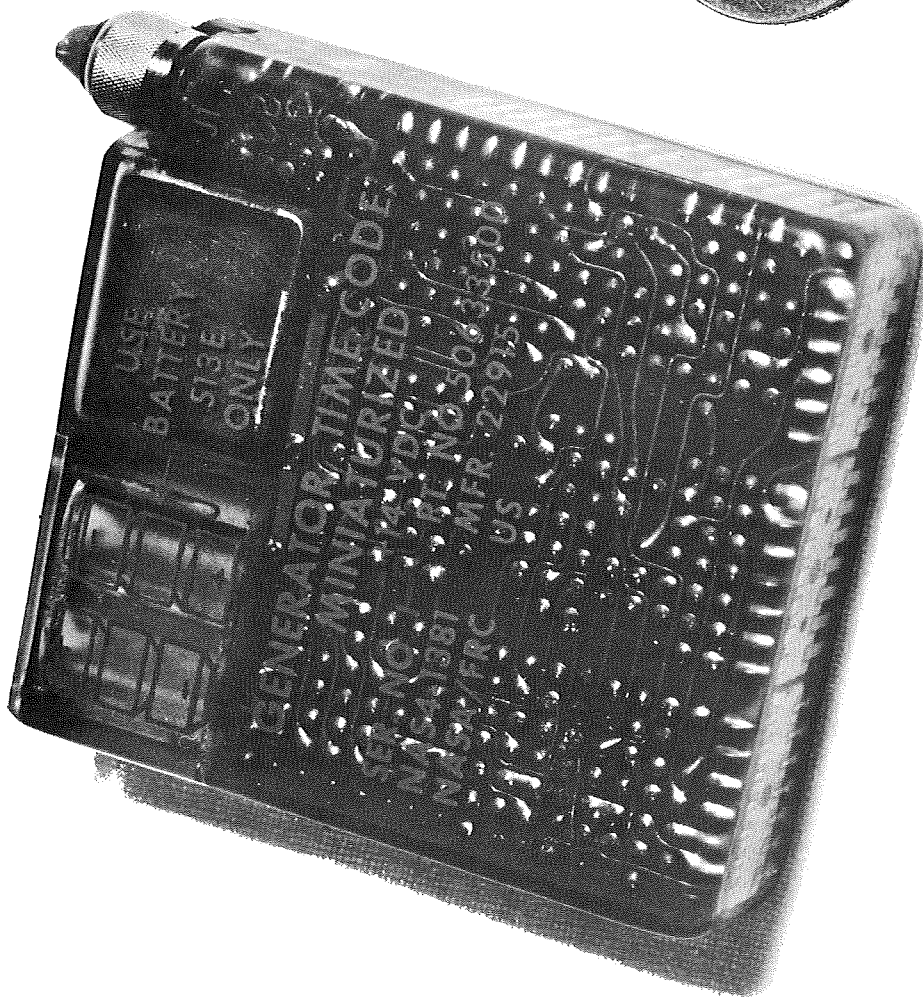
Electrical signals and power are provided through a water-tight, positive locking, miniature Lexan connector. The connector was developed by NASA/MSD for Apollo biomedical instrumentation. It is recessed in the Time Code Generator for added abrasion protection when the unit is not connected in a harness.

The Setting Control and Test Unit, Part No. 50633535, is a system test set used to read the time code produced by the miniature Time Code Generator, to prove that the time code produced is complete, and to provide a means of accurately adjusting the time code to the nearest millisecond. A housing is provided for the miniature Time Code Generator (TCG) when it is connected to the Setting Control and Test Unit. A meter and numerous test points are provided to check the voltages and operation of the Setting Control and Test Unit, and the outputs of the TCG. Power is provided by either internal batteries, or connection to external 115 VAC, 60 cycle sources. The Time Code Generator is protected at all times from damage by excessive voltage.

The Setting Control and Test Unit is mounted in a plastic carrying case, which can be sealed from dust and moisture. It is intended for laboratory use, but is capable of use in the harsher environment of the flight line, and in places where no source of electrical power is available.

Readout of the time code is provided by six, neon numeric indicators. Indication of the presence of marks in the time code is provided by neon indicators.

The pulse generator for setting the Time Code Generator has 7 ranges of frequency, and a stop clock function.



2.0 INTRODUCTION

2.1 Background

The Time Code Generator and the Setting Control & Test Unit were developed and produced by Northrop under NASA Flight Research Center Contract No. NAS4-1381. The Project Engineer was William B. Ellern, assisted by P. F. Ulmer, R. Turrentine and G. Blakesley.

The unit is intended to be used with a biomedical recording system worn by pilots flying high performance aircraft. This necessitated making the unit as small as possible, containing only essential functions so the pilot could wear it with his other instrumentation. Consequently, the Time Code Generator produces only electrical time information. The visual readout and setting functions are contained in a separate unit, the Setting Control and Test Unit.

The unit has currently successfully completed all laboratory testing and is being test flown with various recording systems.

This report concludes the contract by documenting the problems encountered and solved in performance of the contract and making recommendations for future changes. It is divided into two portions; the first dealing with the Time Code Generator, and the second with the Setting Control & Test Unit.

Our thanks go to the vendors who tolerated our impositions to obtain state-of-the-art items early; particularly, R.C.A., N.S.C., Barden Inc. and Teclight.

3.0 ACCOMPLISHMENTS

3.1 Time Code Generator

The initial design of the miniature Time Code Generator was made during the proposal effort on the contract. The design goals set were minimum size (commensurate with environmental factors), minimum power (10 hour battery operation required) and maximum accuracy (.001%).

These goals accentuated our primary problem areas and an immediate survey (May 1968) of these problem areas was made. They were: low power integrated circuits, high power density batteries, high accuracy tuning fork/crystal oscillators, and miniature, positive locking connectors.

The integrated circuit lines of 18 vendors, representing a majority of the industry, were surveyed. Only one specialized in a line of low power logic. Their product required was TWO orders of magnitude less power than any other.

The battery lines of 10 vendors were surveyed. The highest power/volume ratio for a commercially available battery was a silver oxide, hearing aid, button cell. Higher power densities were available in experimental batteries, but these were rejected because of potential supply/cost problems.

An accuracy of .005% represents the boundry between good tuning forks, and average crystal oscillators. The combination of three factors, size, power, and accuracy led to a tuning fork being chosen over a crystal oscillator. The survey turned up one vendor making tuning forks of .002% (+1 second/10 hour period) which was considered adequate for the requirement. Currently, (April 1969) this unit is still unique.

A survey of manufacturers uncovered only two positive locking connectors meeting the size, and environmental requirements imposed. The smaller, Lexan-bodied connector was chosen over a metal bodied unit. It also had a history of development for biomedical instrumentation with the Manned Space Flight Center at Houston, Texas.

The next consideration was packaging. The low power integrated circuits were only available in dual in line (DIL) packages with a limited number of logic combinations. A rough logical design was performed producing a package count of 46 integrated circuits. Dummy DIL packages were examined. The leads could be straightened, indeed twisted 360° without breaking. Based on these facts, cordwood packaging was indicated. Welded wire design of the interconnecting leads was considered, and rejected in favor of printed circuit boards. The buildup of tolerances for the welded wire assembly made it significantly thicker than the printed circuit board version and did not lend itself to quantity production. The final assembly would be embedded in plastic for added environmental protection.

Based on the number of components, their size, and cordwood packaging with a nominal tolerance buildup, a size of .68" x 2.42" x 2.60" (17.3 mm x 61.5 mm x 66.0 mm) was projected. An additional .040" was allowed on each dimension for manufacturing tolerance.

After the first breadboard was made of the digital portion of the circuit, minor problems occurred in the resetting circuit from 23:59:59 to 00:00:00. All of the logic was worked over to further simplify it, further reducing the number of digital integrated circuits to 42 total.

All interconnections were completed on two double sided printed circuit boards.

The breadboard was rebuilt to match the printed circuit wiring. This made it possible to operate each component in advance exactly as it would be used in the final assembly.

Difficulties were found with the linear circuitry. The simple output modulator derived in the proposal design proved inadequate in practice. An active filter was used to change the tuning fork output from a 1 KHz square wave to a IRIG specified sine wave. The active filter caused a phase shift, making it necessary to drive the digital circuitry from the filter output rather than the tuning fork output. A transistor was used to square up the sine wave for the digital circuitry.

Early in the design it was discovered that the external power supply voltage could exceed the amount described in the contract by a factor of 2. This excluded the use of a simple zener diode for overvoltage protection. A flat pack voltage regulator with the associated circuitry was substituted.

An exception was also made to the specified output amplitude. This was resolved by using a different value resistor.

Experience gained during checkout of the breadboard brought to light the realization that the continuous operation of the Time Code Generator could not be checked without use of a Setting Control and Test Unit. It is possible to store and read a single time code on an oscilloscope, but it is almost impossible to read on a scope the full time code as it is generated and changed each second, to verify the proper dynamic operation of all of the circuitry.

The time code readers commercially available read only the time code elements, not the marks, blank spaces, or the number of carrier pulses making up an element in the Time Code. The Setting Control & Test Set does all these. As a consequence final fabrication of the TCG was delayed until the Setting Control and Test Unit became available. Completion of fabrication was further delayed by a problem in fabrication of the tuning fork oscillator. This unit was a new design that consumed less power than any previously designed. The new design used a part which had been advertised but was not actually available. When it became obvious that there would be 6 to 8 months delay in obtaining this part, considerably larger substitute part was obtained. The problem in fabrication was sealing the tuning fork case without crushing the contents. This difficulty was finally resolved by relaxing one dimension and fabricating a special case to contain the fork.

The substitute part in the tuning fork permitted a considerable power reduction over any previously fabricated unit. This additional power margin was needed when it was discovered that at $+20^{\circ}\text{F}$ (-6°C) silver oxide batteries have a tendency to freeze, reducing the total power available. At $+20^{\circ}\text{F}$ (-6°C) the present batteries have sufficient power to permit 10 hours of operation. This "frozen" power is available at room temperature, permitting in excess of 30 hours of continuous operation.

The Time Code Generator was finally assembled, checked out, and ready to encapsulate when four failures of gates occurred. All these failures occurred within a one week period to gates which had been operating without problem for the previous 6 months. The cause was traced to the use of nylon smocks in the clean room where work had been done on the time code generator. When taken off, the smocks produced a charge of several thousand volts, which had been subsequently discharged through the time code generator circuitry.

The time code generator was repaired. Precautions were taken against further re-occurrences. These were procedural, and providing a shorting cap on the unit supplied to be used when it is not connected into a harness. All further units will be fabricated from the new static resistant units now available.

The Time Code Generator was encapsulated and supplied to NASA Flight Research Center without further incident. It has successfully undergone all the tests performed on it. The test and operational history of this unit will be the subject of a subsequent report.

The Time Code Generator is shown in Figure 1. The specifications on the Time Code Generator are given in Appendix 1.

3.2 Setting Control & Test Unit

As originally proposed the Setting Control & Test Unit (SC&TU) consisted of just readouts and a setting control with power supplies and batteries. As work progressed, it became apparent that additional features were needed, thus a series of functions were added for more completely testing both the operation of the Time Code Generator, and the unit's own internal operation. The final item delivered would more accurately be called a "time code generator test set" and could with minor modification be made a piece of general purpose test equipment for any time code generator.

The original design goals set were low cost (because of relaxed environmental factors), portability, and 115 VAC/battery operation. In actual fact, the final design was dictated almost entirely by the readout devices.

The readout device chosen for the SC&TU was a neon indicator tube which operates at + 180V. An inexpensive combination of tube, mounting and integrated circuit driver was selected. This unit was the smallest combination device of

of its kind on the market. To match the readouts' driving circuitry similar 5 volt devices were used in the logic. This necessitated three power supplies and three sets of batteries (+ 200V, + 15V and + 5V). The power supplies, batteries and the mountings required to provide these three voltages represent over half the weight and 2/3 the volume required for the SC&TU.

The design of the Setting Control and Test Unit followed that of the Time Code Generator, although both were required to check each other out. This dilemma in scheduling was to be made up by breadboarding the circuitry and fabricating the final package of the SC&TU in parallel. As these efforts neared completion, notification of a minor delay in delivery of the readouts was received. The actual delay was several months.

When the readouts were finally delivered, difficulties were discovered with high frequency noise affecting the input buffers. This noise was in the 500 KHz to 4 MHz range, of small amplitude and random occurrence. It could not be normally detected on a oscilloscope. It was eliminated by filtering.

The final unit met the design goals so far as they could be met using the readouts selected. The Setting Control & Test Unit **specification** are given in Appendix II.

4.0 RECOMMENDATIONS

4.1 Time Code Generator

The following changes are contemplated on future time code generators.

1. Use static-electricity-resistant integrated circuits.
2. A value analysis of the container for the batteries should be performed and alternate methods of fabrication should be investigated.
3. The critical item to the entire project is the tuning fork. The following suggestions should be pursued as possible means of easing its critical nature; establish alternate sources, provide sufficient time after procurement to verify accuracy and aging rate or if necessary, obtain a 4KHZ fork and count down to 1 KHZ in Time Code Generator.

4.2 Setting Control and Test Unit

The following changes are contemplated on future Setting Control and Test Units.

1. Do not use RTL integrated circuits.
2. Use Dual-in-line integrated circuit packages.
3. Survey the entire display device field for more adequate devices using fewer or lower voltages.
4. The lid should be shallower permitting rubber feet to be put on the main body only. This will permit the unit to be placed on a work bench in vertical as well as horizontal position.
5. The mounting holes in the front panel should be slotted and spaced to permit relay rack mounting.
6. Fuse sizes should be inscribed under the fuse voltages.
7. Battery switch should have three positions, OFF/TRICKLE CHARGE/CHARGE.

8. Readout switch should operate as follows:

OFF - Turns off + 200V and + 3.75V supplied to all logic and displays . The + 14V is supplied to TCG, but not to input buffers.

RUN - Normal continuous readout operation.

HOLD - TCG disconnected (see 9 below). SC & TU will hold last previous reading but TCG continues running.

9. All of the TCG outputs should go from TCG harness connector to the TCG test points and then to the contacts of a seven pole relay controlled by a toggle switch (see 8 above).
10. The input buffers should be redesigned using an AGC control circuit so any Time Code Generator could be connected to the SC&TU.
11. The input buffers should have better filtering for higher frequencies (above 100 KHz)
12. Some additional visual indication of erroneous operation should be provided to check the time code.
13. A digital countdown circuit from 1 MHz instead of a multivibrator should be provided for the setting control oscillator.
14. A separate Readout & Setting Control should be developed for flight line use. This unit should be rugged, low power, battery operated incorporating only the readout and setting control functions. This would eliminate the need for batteries in the SC&TU.

APPENDIX 1

SPECIFICATIONS FOR TIME CODE GENERATOR, MODEL NSL-2 P/N 50633500

Size: 0.72" x 2.46" x 2.64" maximum including connector.

Weight: Under 4.6 ounces (135 grams)

Power (Nominal) Internal: 9 V.D.C.

Power (Nominal) External: 14 V.D.C. at 4.0 mA.

Accuracy: $\pm 0.002\%$ or better over the specified temperature range

Finish: Non-toxic plastics and inks compatible with human environment.

All corners are radiused (3mm or more)

All sharp edges, burrs, nicks and rough spots are removed.

Output (General): IRIG B format accumulated elapsed time counting from time 0 to any preset time of day in seconds, minutes and hours. Day number and accumulated binary seconds not provided in this model. A one second mark is provided on a second output line.

Output (Detailed): Time of day in BCD seconds, minutes and hours. The format is a modified IRIG B format in a modulated carrier serial time code.

(a) Carrier: 1000 Hz sine wave

(b) Amplitude: 500 mV p-p minimum, high amplitude state.

$\pm 10\%$

(c) Modulation Ratio: 3:1

(d) Frame Length: One (1) second containing 100 bits.

(e) Binary One: Five (5) milliseconds at 500 mV p-p.

(f) Binary Zero: Two (2) milliseconds at 500 mV p-p.

- (g) Binary Mark: Eight (8) milliseconds at 500 mV p-p.
- (h) Load: It is suggested the input impedance of the interfacing device be greater than 5000 ohms.
- (i) Other Output: The one second mark output is a +9V, positive going, 100 millisecond long, square pulse starting at the beginning of each frame.

- Inputs:
- (a) Reset; a +9 volt signal lasting at least 1/4 microseconds on the reset line resets the Time Code Generator to zero time.
 - (b) Sec Sync: a series of +9 volt pulses advances the millisecond counters of the Time Code Generator.
 - (c) Time Sync; a series of +9 volt pulses advance the second counter of the Time Code Generator.

Running Time: Using internal batteries a minimum of 10 hours operation is provided. Nominal running times of about 20-30 hours may be expected dependent on the ambient temperature.

Malfunction Protection: No damage will occur to the Time Code Generator when subjected to a reasonable external malfunction as follows:

- (a) Shorting any two pins of the connector including the power input connections. (Obviously shorting the external power will cause arcing and possible melting of the shorting contacts).
- (b) Zero load on any pin of the connector at any time.
The following malfunctions are limited to the power line and will have no effect on the output.
- (c) Excessive voltage to +35 V.d.c. for an indefinite time.

(d) Abrupt loss of voltage.

(e) Ripple, spikes and transients from 0 to +35 V at frequencies to 10 MHz.

Temperature Range (Operating): +20° to +130°F (-6° to +54°C)

Shock and Vibration: MIL-E-5400

Acoustic Noise: Unaffected by Jet Engine run-up.

Pressure: Unaffected by Pressures from 0.5 to 28.0 psia including explosive decompression from 10 psia to 0.5 psia in 5 ± 0.5 seconds.

Salt Water: With mated connectors and sealed battery holder, shall not exhibit arcing, sparking or temperature rise when submerged in sea water to a depth of 6 inches, or subjected to 24 hours of salt spray.

Oxygen Atmosphere: With mated connectors and sealed battery holder, shall not arc, spark or endanger flight safety in a 100% oxygen atmosphere.

APPENDIX 2

SPECIFICATIONS FOR SETTING CONTROL & TEST UNIT, MODEL NSL-100, P/N 50633535

Size: 20.5" x 15" x 11" (52cm x 38cm x 28cm)

Weight: 40.1 lb. (18.2 Kg)

*Power: 115 V.A.C., 60 cps

*Finish: Non-toxic plastics and inks, non-conducting plastic carrying case. All edges radiused, all sharp edges, burrs, etc, removed.

*Readouts: Hours, Minutes and Seconds

*Running Time: 30 minutes min. on internal power.

*Malfunction Protection: No damage to TCG due to any malfunction of the Setting Control & Test Unit.

Controls: READOUT - 3 position - HOLD, OFF, RUN

SYNC - 2 position - SECOND, TIME

PULSE GENERATOR - 8 position rotary switch - (Blank), Hz, (Mark), (Mark), KHz, (Mark), (Mark), MHz.

RESET - Momentary Push Button

ADVANCE - Momentary Push Button

POWER - 3 position - BATTERY, OFF, 115 VAC

BATTERY - 2 position - OFF, CHARGE

DC VOLTAGE CHECK - 4 position rotary switch - OFF, 3.75 V, 14V, 180V

Indicator Lights: MARK LIGHTS - 00, 09, 19, 29, 39, 49, 59, 69, 79, 89, 99.

ERROR LIGHT.

POWER LIGHT.

BATTERY LIGHT.

Test Points: TCG - TIME CODE, 1 SEC, SEC SYNC, TIME SYNC, RESET
14V, GRD.

SC - ERROR, CPI, DATA DET, CP2, MARK SYNC, CP3, GND.

Connectors: 115 VAC - Miniature Twistlock
TCG - ME95185-7 to fit TCG connector
SCOPE - Gnd and 1 SEC signal

Fuses: 3.75 VDC - 3 amp. 8 AG
14 VDC - 1/16 amp. 8 AG
180 VDC - 1/8 amp. 8 AG
115 VAC - 1 amp, 3 AG, Slo Blo

Shock & Vibration: None

*Temperature Range (operating): 60°F to 130°F (15°C to 55°C)

* Items required by contract.