NATIONAL RADIO ASTRONOMY OBSERVATORY
GREEN BANK, WEST VIRGINIA

ELECTRONICS DIVISION INTERNAL REPORT No. 247

5 MHz FREQUENCY STANDARDS COMPARATOR

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MARCH 1984

NUMBER OF COPIES: 150

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The Frequency Standards Comparator was built to detect phase noise and drift between two 5 MHz signals in the range from 200 kHz down to about 10^4 sec. The higher frequencies are provided at a fixed scale factor and full bandwidth for external analysis. Lower frequency components with periods from about 0.1 to 10^4 sec may be filtered and amplified before being displayed on a meter or external recorder. The two signals must be tracking in phase with sufficient accuracy to stay within the fullscale limits chosen for the observation period. The original unit was designed by S. Weinreb in 1969. Since then several revisions have been made to improve stability, and two additional units have been built though the basic design remains the same.

Referring to Figure 1, the 5 MHz input at A enters through an isolation transformer to reduce power line modulation. A vernier attenuator allows manual adjustment of the level to mid-scale (100) on the detector meter for best phase detector performance. A 100 ps CALibrate switch provides a fixed delay change to check unit calibration and as a marker for chart recorder scale factor. The coarse phase offset switch permits full phase rotation in 10 ns (18 degree) steps for setting the output near the correct null.

The B channel is similar except the CAL switch is omitted and the phase offset circuit is a voltage controlled capacitor for fine phase adjustment. The details of these circuits are shown in Figure 2. Following the phase adjustment and level monitoring circuits, the two signals are amplified and combined in a double balanced mixer phase detector. The difference components are amplified by a low noise op amp and made available at the SCOPE output jack. This output level is 0.33 mV/ps with a frequency range of dc to 200 kHz. Figure 3 shows the details of these circuits. The first op amp feeds signal processing circuits which permit selection of phase or frequency monitoring, time constants and the scale factor for the recorder output and the meter display. These circuits are shown in Figure 4.

Most of the design effort since the original unit was built has been to improve phase stability vs. temperature. The original 5 MHz amplifiers were changed and improved with better capacitors and transistors. After those improvements, the worst offenders were transformers and phase shift network components. The following describes some of the problems encountered.

In the original design a Relcom BT8 transformer was used at the input of the phase offset units. These devices measured 11 to 14 ps/$^{\circ}$C. Four other models by three manufacturers also gave disappointing results. A unit was then built using Ferroxcube 3B7 material that measured 0.22 ps/$^{\circ}$C, an order of magnitude better than the best commercial unit.

The varicap diode has a temperature coefficient (tempco) that varies from about 2000 ppm/$^{\circ}$C at 0 V to 120 ppm at 30 V. Since most of the useful range is at low voltage the problem is major. By setting the lower voltage limit at 0.5 V, the maximum coefficient is about 1000 ppm/$^{\circ}$C or 20 ps/$^{\circ}$C in the circuit. Simply mounting the diode in a small component oven was not the end of the problem. Heat loss through the leads had to be minimized and balanced against over compensation in the oven control. The thermal variation was eventually improved by a factor of about 40 by modifying the oven.

The tempco of the step phase shift components is also a problem. The capacitors are < 30 ppm/^{o}C (NPO) and the resistors are < 50 ppm/^{o}C selected for < 15 ppm/^{o}C. At the worst settings (0 and 180^{o}), a 15 ppm/^{o}C component produces 0.5 ps/^{o}C drift. Impedance changes in the emitter follower network drivers produce a maximum shift of about 2 ps/^{o}. This error is a function of switch position and must be corrected in the driver circuit. The solution was to install an active bias circuit to change the emitter current to hold the impedance constant. With these changes we have once again ended our temperature stability improvement project. Overall performance measured < 1.5 ps/^{o}C though this figure has not been verified for all phase settings. If further improvement is ever required, an overall reduction of temperature change on the phase offset units by a factor of 10 would make them comparable to the phase detector which is < 0.1 ps/^{o}C.

Power line components in the output add to the overall noise for some tests and prevent a check of these component levels on the sources under test. Power supply ripple levels have been reduced by adding a second set of regulators. Magnetic shielding was added to reduce 60 Hz fields in the phase detector. The double-balanced mixer is the component most sensitive to these fields.

S. Weinreb has written a test program for the Apple computer (EDIR 232) to compute Allan variance using this phase comparator and the ADIOS A/D module (EDIR 212). This system was used in April 1983 to compare two hydrogen maser frequency standards. The accuracy of the test setup was more than one order of magnitude better than the specifications on the maser in the range from one to 10^4 sec. The residual variance fell linearly from $2.5 \cdot 10^{-14}$ at 1 sec to $1 \cdot 10^{-16}$ at 1000 sec. Over the next decade the variance remained below $2 \cdot 10^{-16}$. See Figure 5.

Acknowledgement

Acknowledgement is given to Lewis Beale for the construction and extensive testing of these units.

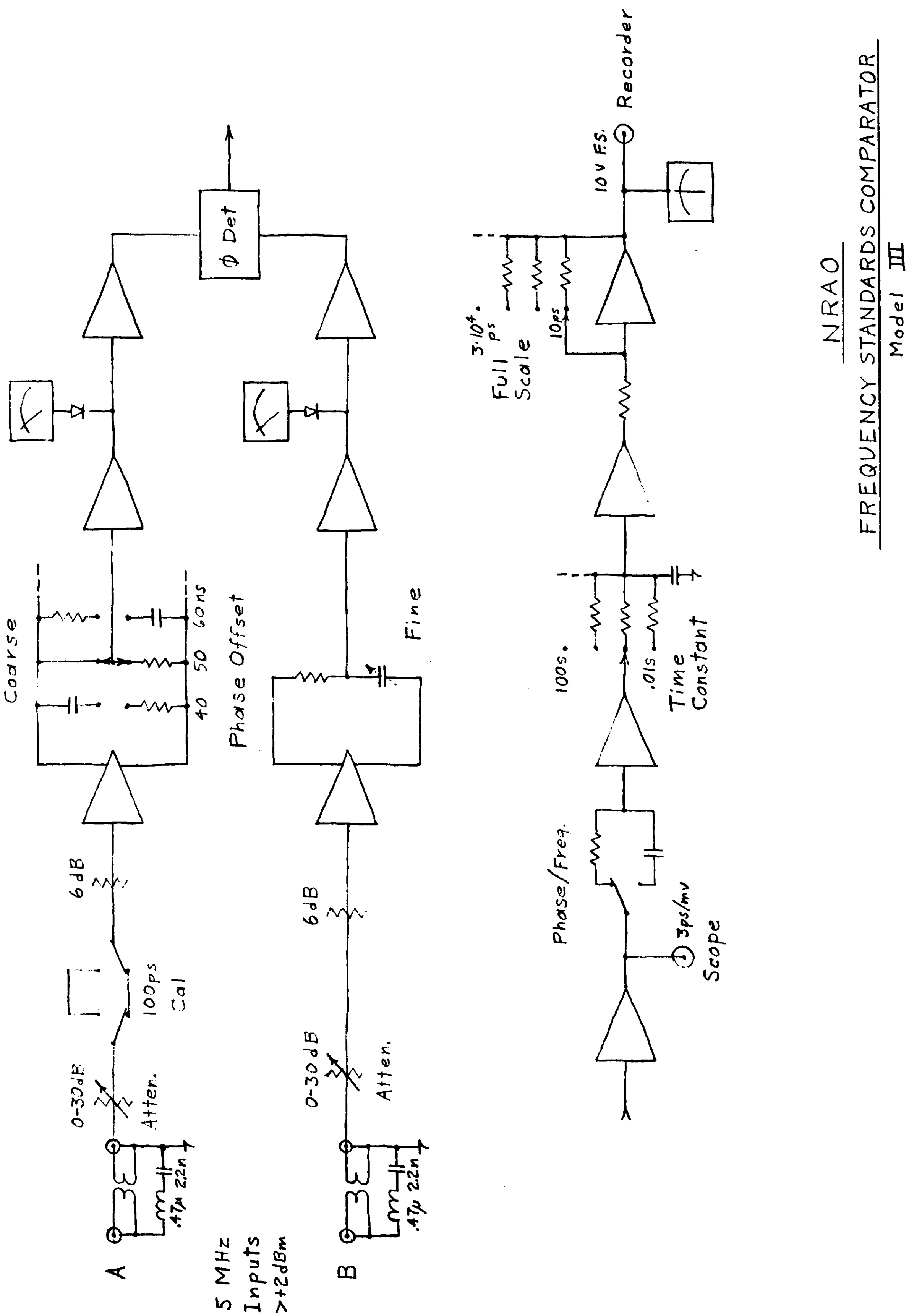
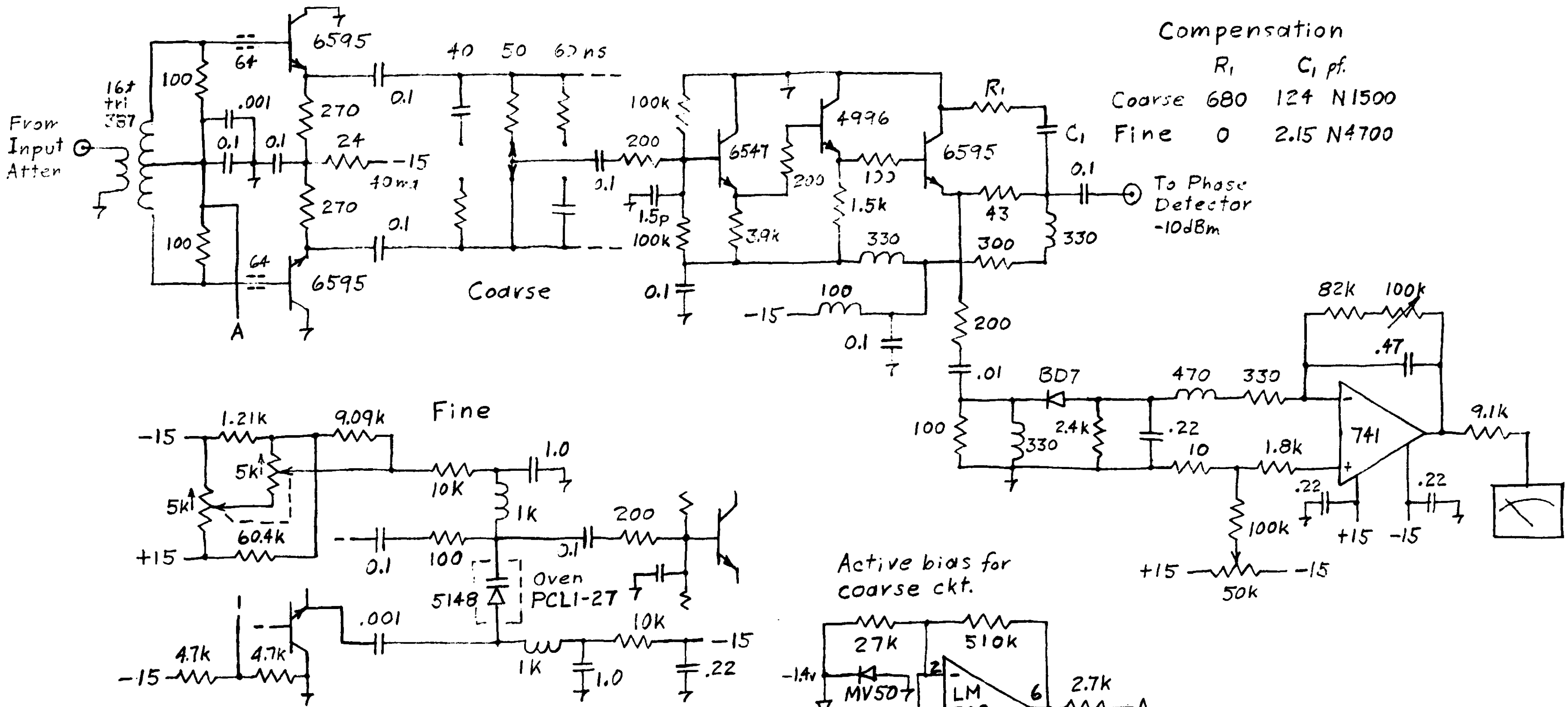

A
B
5 MHz
Inputs
>+2dBm
.47μ
2.2n
0-30dB
Atten.
100ps
Cal
6dB
Coarse
40
50
60ns
Phase Offset
Fine
φ Det
Phase/Freq.
3ps/mv
Scope
100s.
.01s
Time
Constant
Full
Scale
3·10⁴ ps
10ps
10 V F.S.
Recorder
NRAO
FREQUENCY STANDARDS COMPARATOR
Model III

Figure 1

Compensation

	R_1	C_1 pf.
Coarse	680	124 N1500
Fine	0	2.15 N4700

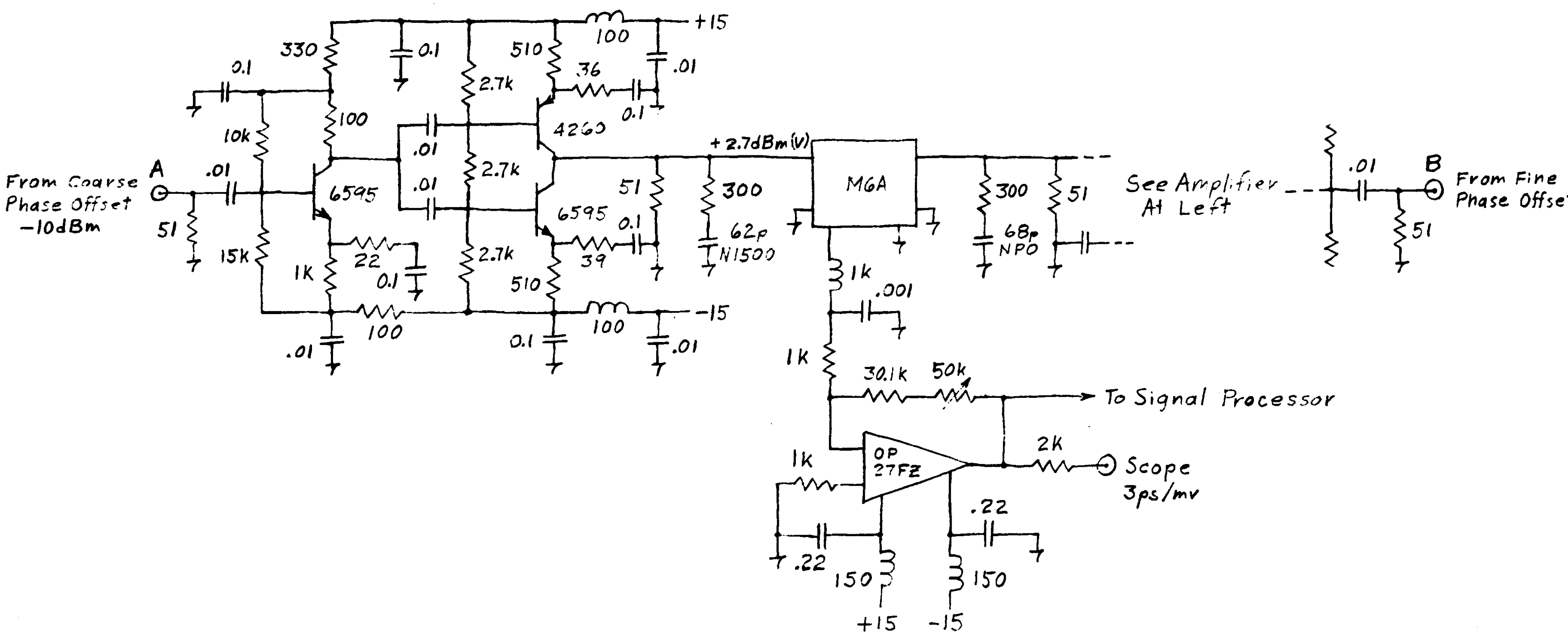


Component Values for Coarse Phase Switch

Delay, ns		R	Cpf
0	100	137	227
10	110	113	199
20	120	86.6	181
30	130	57.6	171
40	140	28.8	159
50	150	196	Short
60	160	191	1036
70	170	187	516
80	180	174	353
90	190	158	272

PHASE OFFSET UNITS

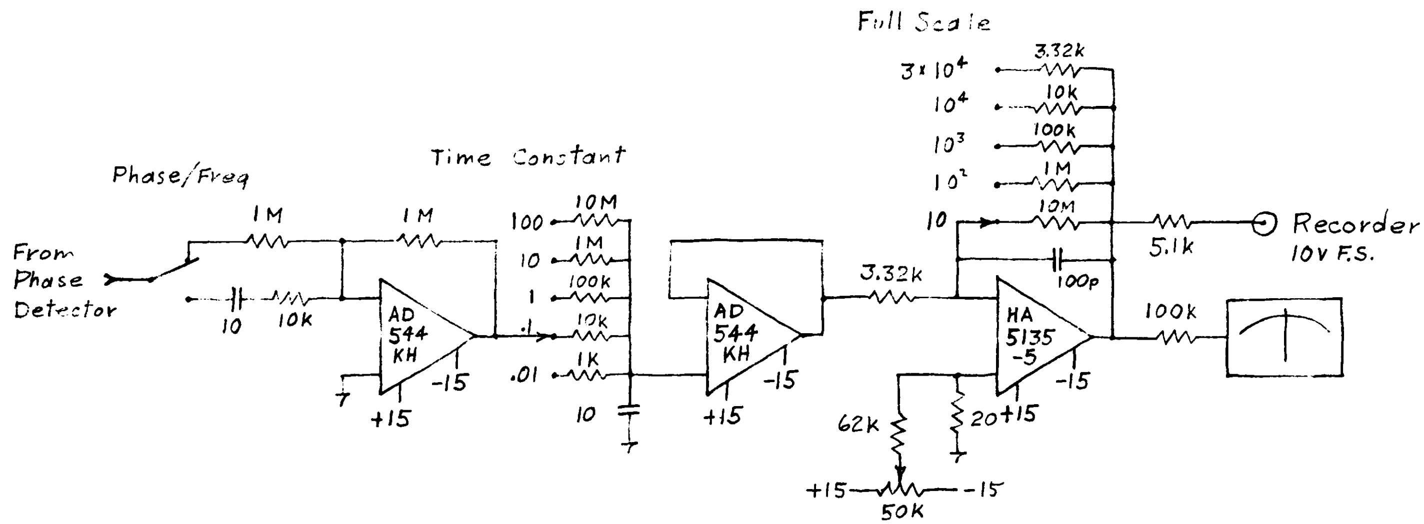
Model III



PHASE DETECTOR

Model III

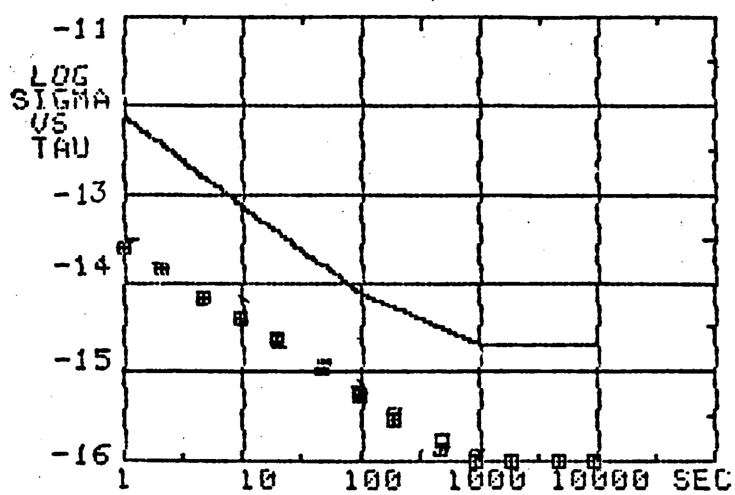
Figure 3



SIGNAL PROCESSOR

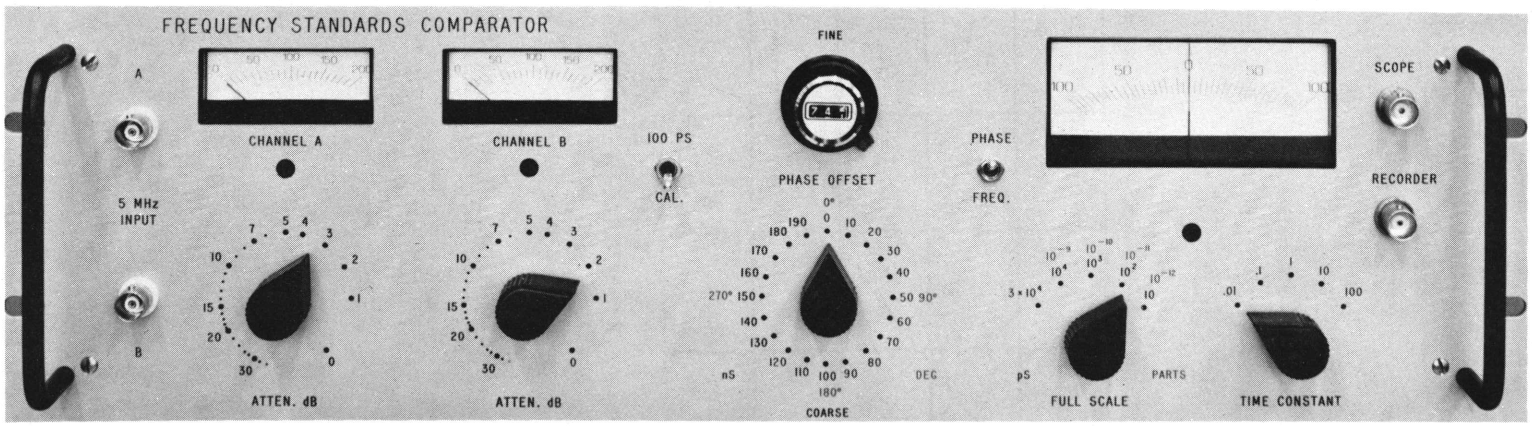
Model III

Figure 4



Allan Variance

Figure 5



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