This ATM presents a Reliability analysis of the Lunar Day Counter, the Resettable Solid State Timer (RSST) and the RSST with the Lunar Day Counter as back-up for the automatic turn-off function for the ALSEP flight equipment. The analysis is based on a parts count, average failure rates and two (2) years operation.

The Lunar Day Counter was proposed by NASA, MSC Houston and presented to BxA for evaluation. This analysis examines the compatibility of the counter with the ALSEP design and identifies the necessary modifications to the Lunar Day Counter.

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Bendix

Aerospace Systems Division

RSST/Lunar Day Counter
Reliability Analysis

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SCOPE

This ATM documents a reliability analysis of the Lunar Day Counter, the Resettable Solid State Timer (RSST) and the RSST with the Lunar Day Counter as back-up for automatic turn-off function for the ALSEP System at the end of 2 years operation.   The analysis includes:

1.   Reliability Prediction of the Lunar Day Counter in the configuration as proposed by MSC.

2.   Reliability Prediction of the Lunar Day Counter, modified to be compatible with the ALSEP System.

3.   Reliability Prediction of the RSST.

4.   Reliability Prediction of the Lunar Day Counter in parallel with that portion of the RSST which provides system turn-off.

LUNAR DAY COUNTER RELIABILITY PREDICTION

This analysis is based on a 4 lunar day counter as proposed by NASA, MSC.   Figure 1 shows the schematic of the counter.   The count period can be varied by taking the output from various pins of the RCA CD 4004 module as noted in Note 1 of the schematic.   In this analysis the output is taken from pin 9, providing 3 counter stages for counting 4 lunar days or 4 earth months.

A reliability block diagram and prediction for the MSC Lunar Day Counter is shown in Figure 2.   Since the lunar day counter is provided with a manual reset capability only and cannot be reset by command, the counter will count out in 4 months giving a probability of success for 2 years equal to "0".   The counter does not incorporate a power on reset capability. Without a power on reset capability, each stage of the counter will come on in an undetermined state of "1" or "0".   For a successful 4 month operation, all stages must come on in the "0" state.   The 4 month counter utilizes 3 stages, giving a probability of success for 4 months of $(0.5)^3$ or 0.065.

MODIFIED LUNAR DAY COUNTER

A block diagram of a lunar day counter modified to incorporate a power on reset and a command reset capability is shown in Figure 3.

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Figure 4 presents a reliability block diagram and prediction for the modified lunar day counter with a probability of success for 2 years operation of 0.99836. The block diagram and prediction for an early output is shown in Figure 5. The probability of an early output from the modified counter for a 2 year period is 0.00055.
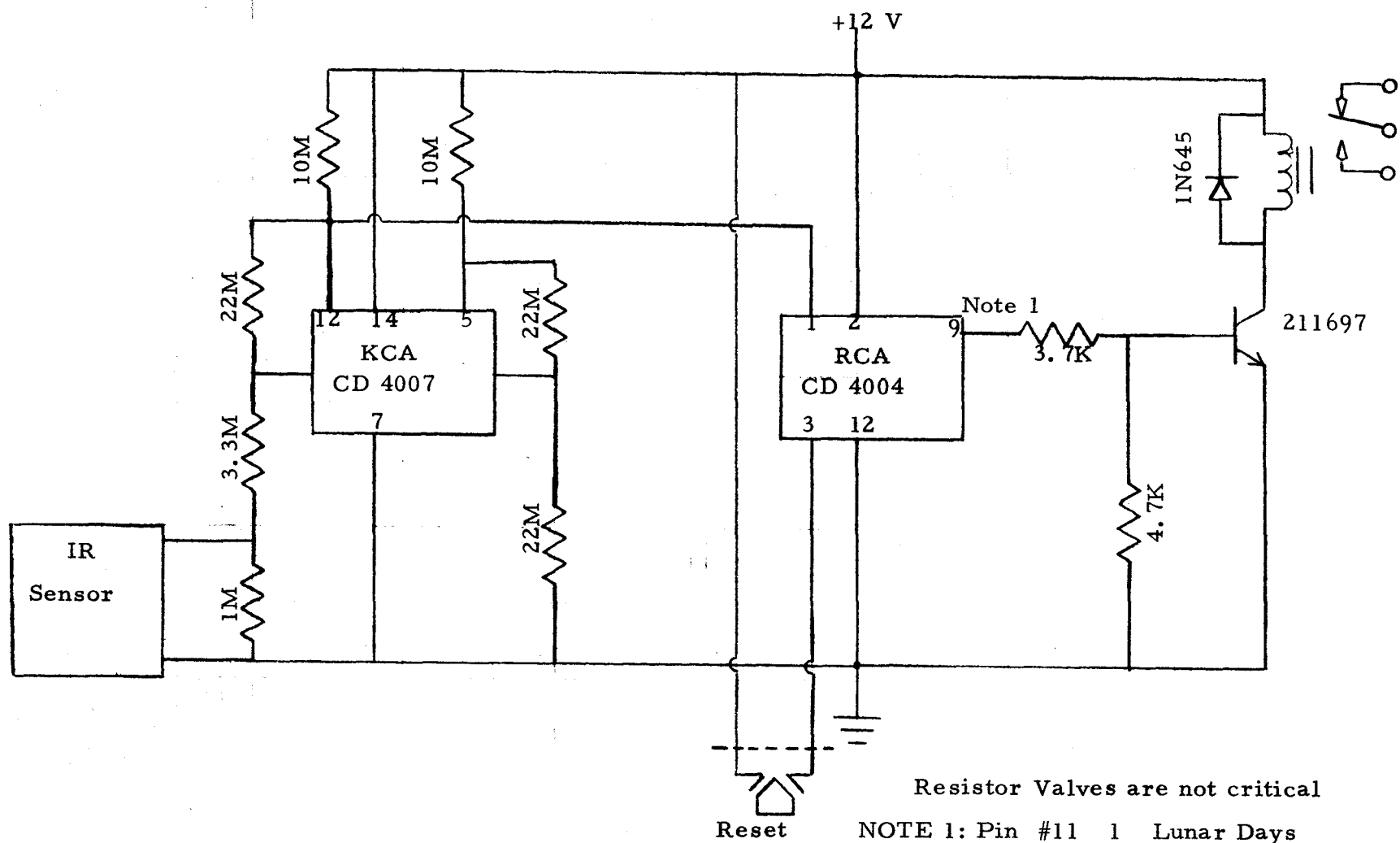
RSST PREDICTION

A functional block diagram of the RSST is shown in Figure 6. A reliability block diagram and prediction for 2 years operation is presented in Figure 7. The probability of success for 2 years operation for the RSST is 0.99784. The probability of an early output from the RSST over a 2 year period is 0.00035 as shown in Figure 8.

RSST/LUNAR DAY COUNTER BACK-UP

Figure 9 presents an analysis of the Lunar Day Counter in parallel with only those portions of the RSST necessary to provide a 2 year output. The probability of success for 2 years operation of this redundant configuration is 0.999996. The probability of an early output of this configuration is 0.00090.

CONCLUSIONS

This analysis indicates that the RSST/LUNAR DAY COUNTER redundant configuration would improve the probability of success for a 2 year turn-off function by a large margin. However, with a probability of success for the RSST of 0.99784 and a probability of an early output of 0.00035 for 2 years, a trade-off analysis of reliability improvement versus weight, volume, power, budget and schedule impact would be required to determine the desirability of a RSST/Lunar Day Counter redundant configuration.

+12 V

1N645

211697

10M

10M

22M

22M

22M

3.3M

1M

KCA
CD 4007

12 14   5

7

RCA
CD 4004

1   2   9

3   12

Note 1

3.7K

4.7K

IR
Sensor

Reset

Resistor Valves are not critical

NOTE 1: Pin #11   1   Lunar Days

"	10	2	"	"
"	9	4	"	"
"	7	8	"	"
"	6	16	"	"
"	5	32	"	"
"	4	64	"	"

Figure 1 MSC Lunar Day Counter

```
+------------------+     +------------------+     +------------------+     +------------------+
|                  |     |  Inverter Amp    |     |   4 Month        |     |    4 Month       |
|  I. R.  Sensor   |-----|       &          |-----|   Counter/       |-----|   Output relay   |
|                  |     | Schmitt Trigger  |     |   Relay Driver   |     |                  |
+------------------+     +------------------+     +------------------+     +------------------+
```
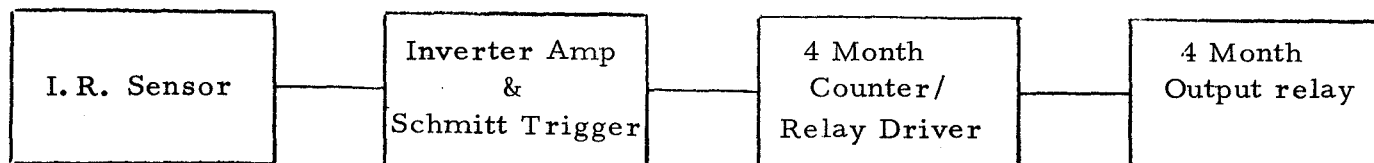
Probability of Success for 2 Years:

$R_{2yr} = 0$ The counter manual reset function is incompatible with the ALSEP
System. The inability to reset the counter by command will
provide an early output at 4 months. (Ref Note)

Probability of Success for 4 Months:
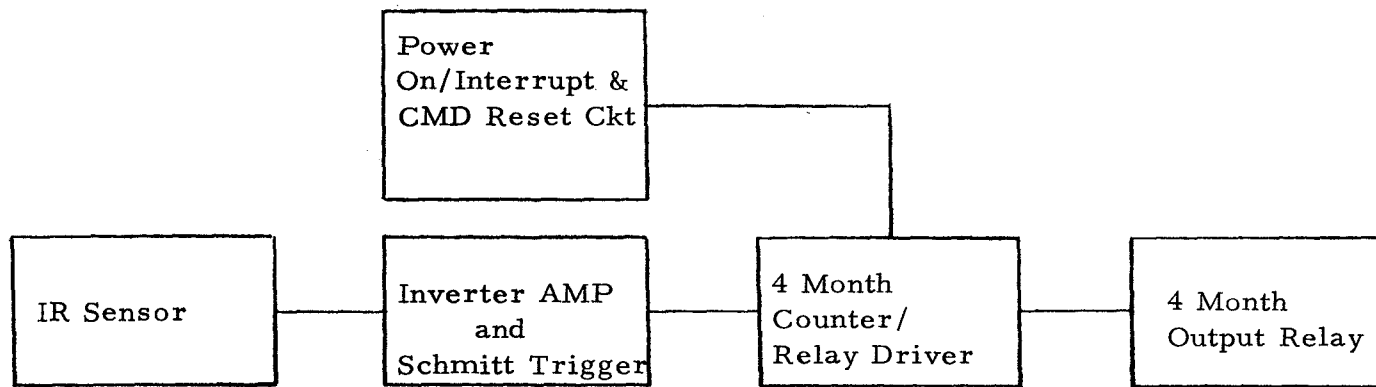
$R_{4mo} = 0.065$
The lunar day counter does not incorporate a "power on" reset
circuit. Without a "power on" Reset capability the 4 month
counter will turn on in an undetermined state, (i.e.: each stage
of the 4 month counter will come up "1" or "0".) for a successful
4 month operation all stages must come up in the "0" state.

NOTE:
Resetting the counter to the all "0" state is accomplished
by a high level on the reset line. The ALSEP command
provides a low level or negative pulse to the counter
reset line. Additional circuitry is required to provide a
command reset capability.

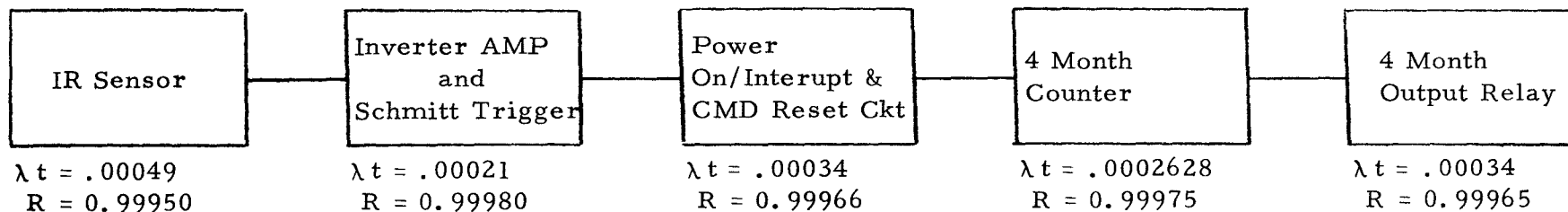Figure 2 Lunar Day Counter (4 Earth Month) Block Diagram

Figure 3 Modified Lunar Day Counter Fu__ _ional Block Diagram

```
                        ┌──────────────────┐
                        │ Power            │
                        │ On/Interrupt &   │
                        │ CMD Reset Ckt    │
                        └──────────────────┘

┌──────────────┐   ┌──────────────────┐   ┌──────────────┐   ┌──────────────┐
│              │   │ Inverter AMP     │   │ 4 Month      │   │              │
│ IR Sensor    │   │ and              │   │ Counter/     │   │ 4 Month      │
│              │   │ Schmitt Trigger  │   │ Relay Driver │   │ Output Relay │
└──────────────┘   └──────────────────┘   └──────────────┘   └──────────────┘
```

Reset Circuit Similar to the RSST Reset Circuit.

All Elements Could be Redundant to Enchance Reliability.

Figure 4 Modified Lunar Day Counter Reliability Block Diagram

```
┌──────────────┐  ┌──────────────────┐  ┌──────────────────┐  ┌──────────────┐  ┌──────────────┐
│              │  │ Inverter AMP     │  │ Power            │  │ 4 Month      │  │ 4 Month      │
│ IR Sensor    │  │ and              │  │ On/Interupt &    │  │ Counter      │  │ Output Relay │
│              │  │ Schmitt Trigger  │  │ CMD Reset Ckt    │  │              │  │              │
└──────────────┘  └──────────────────┘  └──────────────────┘  └──────────────┘  └──────────────┘
```

$\lambda t = .00049$ $\lambda t = .00021$ $\lambda t = .00034$ $\lambda t = .0002628$ $\lambda t = .00034$

$R = 0.99950$ $R = 0.99980$ $R = 0.99966$ $R = 0.99975$ $R = 0.99965$

Probability of Success for 2 years: $R_{T(2 \text{ yrs})} = 0.99836$

Probability of Success for 4 months: $R_{T(4 \text{ mo})} = 0.99998$

Figure 5 Modified Lunar Day Counter Inadvertent Output Block Diagram

```
┌─────────────────┐   ┌─────────────────┐   ┌─────────────────┐   ┌──────────────────────────┐
│                 │   │                 │   │                 │   │                          │
│  Fast Count     │   │  Reset Ckt      │   │  Relay Driver   │   │  Relay Short             │
│  λ = 0.00038    │   │  Failures       │   │  Short          │   │  λ = 0.001 x 10⁻⁵        │
│                 │   │  λ = 0.00099    │   │  λ = 0.00079    │   │                          │
│                 │   │                 │   │                 │   │                          │
└─────────────────┘   └─────────────────┘   └─────────────────┘   └──────────────────────────┘
```

$$\lambda = 0.00316$$
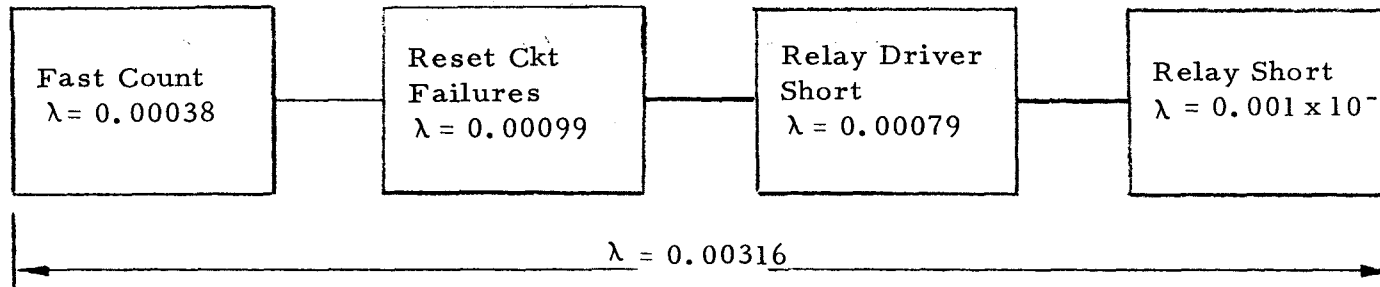
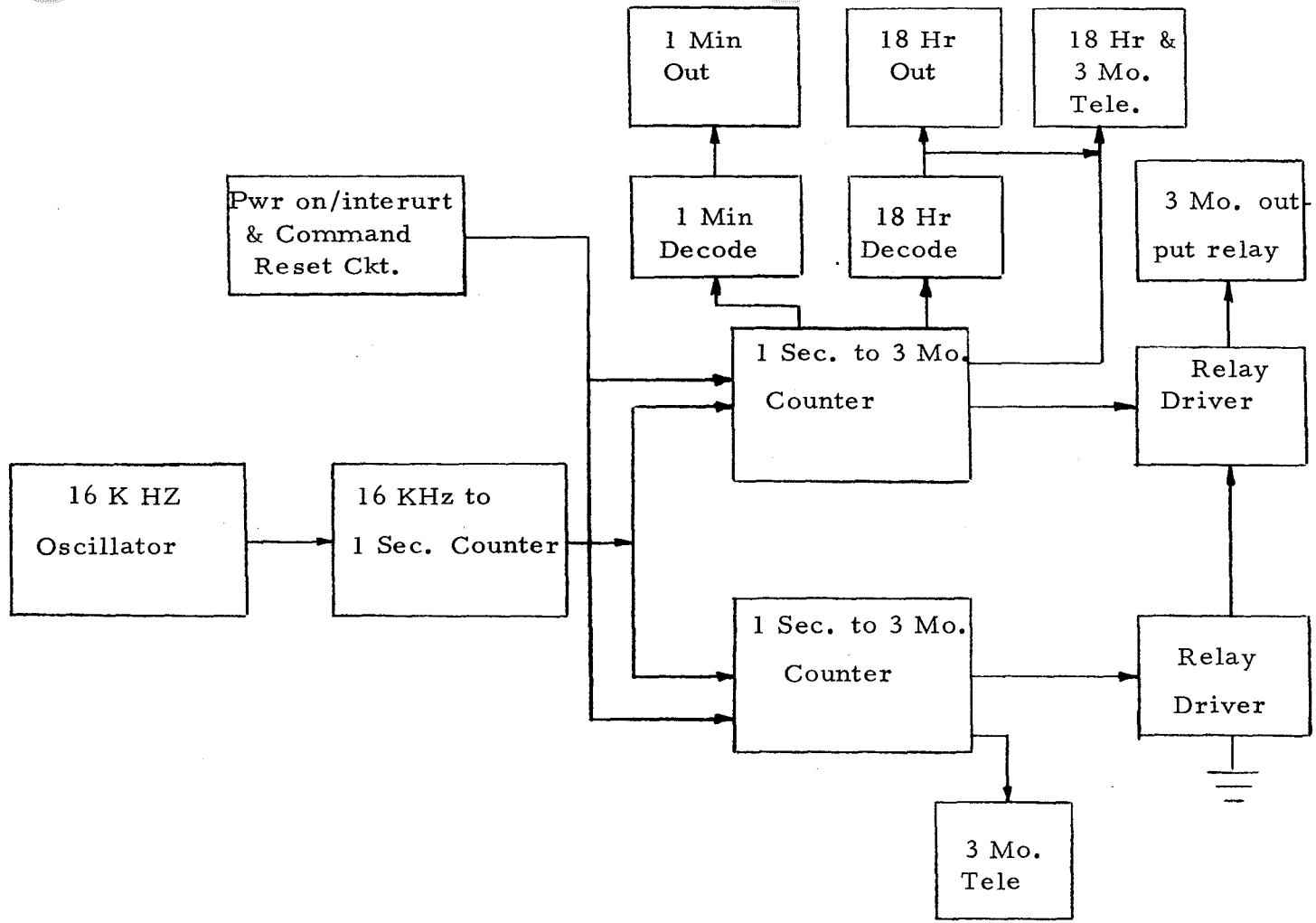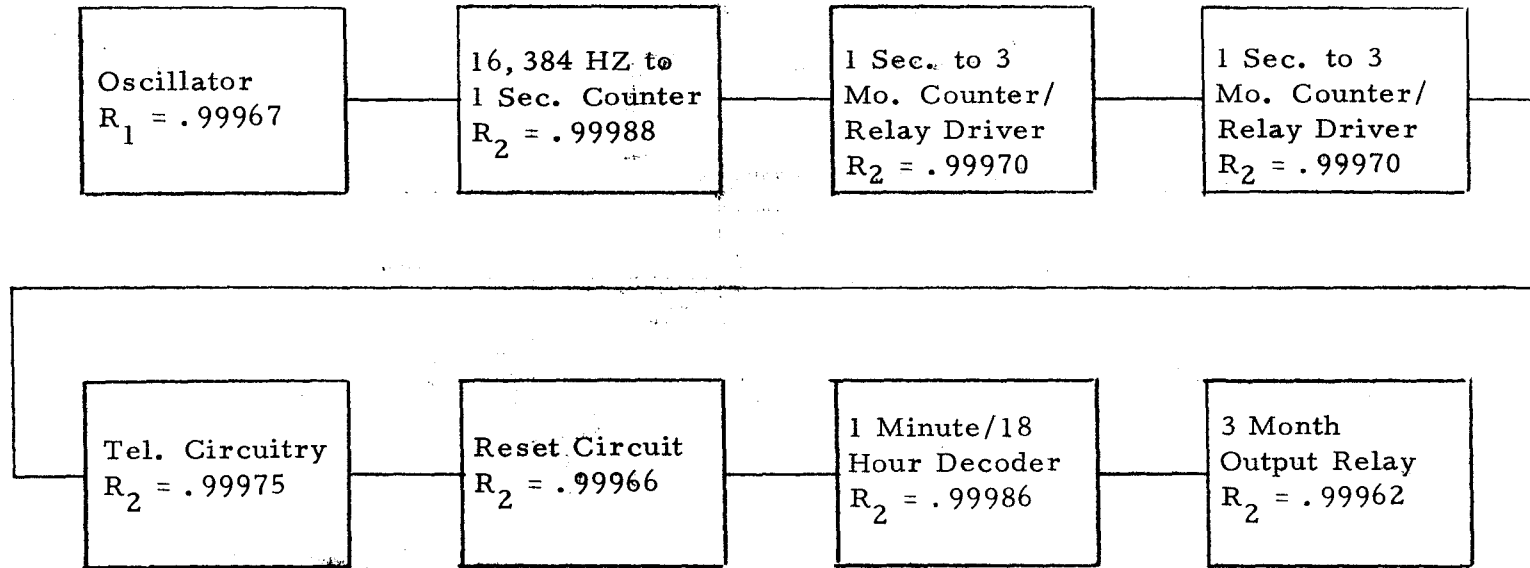Probability of Inadvertent Output: $Q_{Inad} = (1 - e^{-\lambda t})$

$$= 0.00055$$

Figure 6 Resettable Solid State Timer (RSST) Functional Block Diagram

Figure 7 RSST Reliability Block Diagram

Oscillator $R_1 = .99967$	16,384 HZ to 1 Sec. Counter $R_2 = .99988$	1 Sec. to 3 Mo. Counter/ Relay Driver $R_2 = .99970$	1 Sec. to 3 Mo. Counter/ Relay Driver $R_2 = .99970$

Tel. Circuitry $R_2 = .99975$	Reset Circuit $R_2 = .99966$	1 Minute/18 Hour Decoder $R_2 = .99986$	3 Month Output Relay $R_2 = .99962$

Probability of Success for 2 Years: $R_{T(2\ yrs)} = .99784$

NOTE: Prediction Based on Part Count and Average Failure Rates.

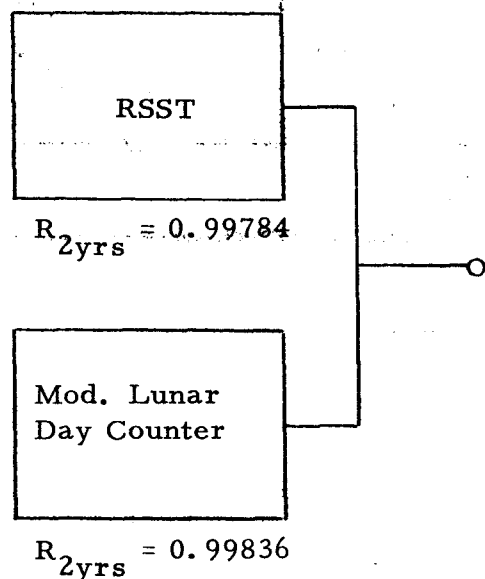Figure 8 Inadvertent Output Block Diagram

Relay Short $\lambda = 0.001 \times 10^{-5}$ $R = .99982$	Reset Failure $\lambda = 0.00099$ $\times 10^{-5}$ $R = .99983$
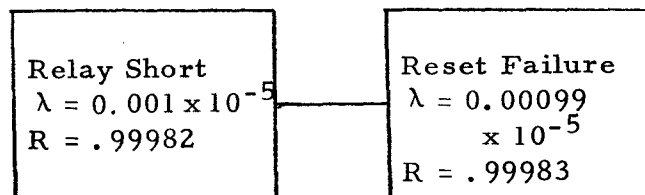
Probability of Inadvertent Output for 2 Years:

$$Q_{Inad} = 0.00035$$

$$\boxed{\text{RSST}}$$

$$R_{2yrs} = 0.99784$$

$$\boxed{\begin{array}{l}\text{Mod. Lunar}\\\text{Day Counter}\end{array}}$$

$$R_{2yrs} = 0.99836$$

Probability of Success of RSST/Modified Lunar Day
Counter Redundant Configuration for 2 Years:

$$R_{T-2yrs} = 0.99784 + 0.99836 - (0.99784)(0.99836)$$

$$= 0.999996$$

Probability of Inadvertent Output of RSST/Modified Lunar Day
Counter Redundant Configuration for 2 Years:

$$Q_{Inad} = 0.00090$$