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Department  
**Code 311**  
From  
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Department  
**7809**  
Subject  
**Radiation Report on M54HC4020YBF**  
**GG5/WIND/WAVES Control No. 5729**

**PPM-92-0094**  
Date  
**March 9, 1992**  
Location  
**Lanham**  
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A radiation evaluation was performed on the M54HC4020YBF to determine the total dose tolerance of these parts. A brief summary of the test results is provided below. For detailed information, refer to Tables I through IV and Figure 1.

The total dose testing was performed using a cobalt-60 gamma ray source. During the radiation testing, four parts were irradiated under bias (see Figure 1 for bias configuration), and one part was used as a control sample. The total dose radiation steps were 5, 10, 15, and 20 krads\*. After 20 krads, the parts were annealed at 25°C for 168 hours and at 100°C for 168 hours. The dose rate was between 55 and 116 rads/hour, depending on the total dose level (see Table II for radiation schedule). After each radiation exposure and annealing treatment, the parts were electrically tested at 25°C according to the test conditions and the specification limits listed in Table III. These tests included three functional tests at 1 MHz after each radiation and annealing step.

All parts passed all three functional tests on irradiation to 15 krads. However, three parts failed functionally at  $V_{cc} = 2$  V after 20 krads of exposure. The parts recovered and passed functionally on the subsequent annealing treatments under bias at 25°C for 168 hours and at 100°C for 168 hours. Parametrically, all parts passed every test through 10 krads of exposure. However, after 15 krads, three parts were unable to maintain a logic high state on output Q1. During the VOH tests it was observed that output Q1 would momentarily go to a logic high state before returning to the logic low state. This unexpected return to logic low created an additional clock pulse causing the counter to increment. Appendix A provides a detailed explanation of this problem. In addition, after 15 krads all four parts exceeded the specification limit of 4  $\mu$ A for ICCL and three parts exceeded the specification limit of 4  $\mu$ A for ICCH with readings up to 26  $\mu$ A. The parts continued to degrade on further irradiation to 20 krads. At this stage all four parts were unable to maintain a logic high state on output Q1. The ICC parameters continued to increase with ICCL reaching 430  $\mu$ A and ICCH reaching 35  $\mu$ A. The parts showed some recovery in the ICC parameters upon annealing at 25°C for 168 hours. ICCL and ICCH decreased to a maximum of 220  $\mu$ A and 5  $\mu$ A respectively. Continued recovery was observed upon annealing at 100°C for 168 hours. All four parts passed all VOH tests and were able to maintain the logic high state. However, two parts marginally exceeded the specification limits for ICCL with a maximum reading of 20  $\mu$ A.

Table IV provides the mean and standard deviation values for each parameter after each radiation exposure and annealing treatment. It also provides a summary of the functional test results after each radiation/annealing step. Any further details about this evaluation can be obtained upon request. If you have any questions, please call me at (301)731-8954.

\* In this report, the term "rads" is used as an abbreviation for rads (Si).

TABLE I. Part Information

|   |                         |
|---|-------------------------|
| Generic Part Number:                    | 54HC4020                |
| GGG/WIND/WAVES<br>Part Number:          | M54HC4020YBF            |
| Control Number:                         | 5729                    |
| Charge Number:                          | C23414                  |
| Manufacturer:                           | S G S Thomson           |
| Lot Date Code:                          | 8919                    |
| Quantity Tested:                        | 4                       |
| Serial Numbers of<br>Radiation Samples: | 53, 54, 55, 56          |
| Serial Number of<br>Control Sample:     | 57                      |
| Part Function:                          | 14 Stage Binary Counter |
| Part Technology:                        | CMOS                    |
| Package Style:                          | 16-pin DIP              |
| Test Engineer:                          | T. Scharer              |

TABLE II. Radiation Schedule for M54HC4020YBF

| EVENTS   | DATE     |
|--|----------|
| 1) Initial (Pre-Irradiation) Electrical Measurements | 01/28/92 |
| 2) 5 KRAD IRRADIATION (74 rads/hour)                 | 01/31/92 |
| POST 5 KRAD ELECTRICAL MEASUREMENT                   | 02/03/92 |
| 3) 10 KRAD IRRADIATION (116 rads/hour)               | 02/03/92 |
| POST 10 KRAD ELECTRICAL MEASUREMENT *                | 02/06/92 |
| 3) 15 KRAD IRRADIATION (55 rads/hour)                | 02/06/92 |
| POST 15 KRAD ELECTRICAL MEASUREMENT                  | 02/10/92 |
| 4) 20 KRAD IRRADIATION (115 rads/hour)               | 02/10/92 |
| POST 20 KRAD ELECTRICAL MEASUREMENT                  | 02/12/92 |
| 5) 168 HOURS ANNEALING AT 25°C                       | 02/12/92 |
| POST 168 HOURS ELECTRICAL MEASUREMENT                | 02/20/92 |
| 6) 168 HOURS ANNEALING AT 100°C                      | 02/20/92 |
| POST 168 HOURS ELECTRICAL MEASUREMENT                | 02/27/92 |

\* Anomalous Event: The Post 10 krad Electrical Measurements were delayed one day due to Automated Test Equipment problems. During this time the parts were maintained under bias at 25°C.

Notes:

- All parts were radiated under bias at the cobalt-60 gamma ray facility at GSFC.
- All electrical measurements were performed off-site at +25°C.
- All annealing steps were performed under bias.

Table III. Electrical Characteristics of M54HC4020YBF

FUNCTIONAL TESTS PERFORMED

| PARAMETER | VCC  | VIL  | VIH  | CONDITIONS   | PINS | LIMITS OVER TEMP.    |
|-----------|------|------|------|--------------|------|----------------------|
| FUNCT 1   | 2.0V | 0.0V | 2.0V | FREQ=1.0 MHz | I/O  | VOL<1.00V; VOH>1.00V |
| FUNCT 2   | 4.5V | 0.0V | 4.5V | FREQ=1.0 MHz | I/O  | VOL<2.25V; VOH>2.25V |
| FUNCT 3   | 6.0V | 0.0V | 6.0V | FREQ=1.0 MHz | I/O  | VOL<3.00V; VOH>3.00V |

DC PARAMETRIC TESTS PERFORMED

| PARAMETER | VCC  | VIL   | VIH   | CONDITIONS  | PINS | LIMITS @ 25°C    |
|-----------|------|-------|-------|-------------|------|------------------|
| VOH1      | 2.0V | 0.50V | 1.50V | LOAD= -20uA | OUTS | > 1.90V ; <2.0V  |
| VOH2      | 4.5V | 1.35V | 3.15V | LOAD= -20uA | OUTS | > 4.40V ; <4.5V  |
| VOH3      | 6.0V | 1.80V | 4.20V | LOAD= -20uA | OUTS | > 5.90V ; <6.0V  |
| VOH4      | 4.5V | 0.50V | 1.50V | LOAD= -4mA  | OUTS | > 4.18V ; <4.5V  |
| VOH5      | 6.0V | 1.80V | 4.20V | LOAD=-5.2mA | OUTS | > 5.68V ; <6.0V  |
| VOL1      | 2.0V | 0.50V | 1.50V | LOAD= +20uA | OUTS | > 0.0V ; <0.10V  |
| VOL2      | 4.5V | 1.35V | 3.15V | LOAD= +20uA | OUTS | > 0.0V ; <0.10V  |
| VOL3      | 6.0V | 1.80V | 4.20V | LOAD= +20uA | OUTS | > 0.0V ; <0.10V  |
| VOL4      | 4.5V | 0.50V | 1.50V | LOAD= +4mA  | OUTS | > 0.0V ; <0.26V  |
| VOL5      | 6.0V | 1.80V | 4.20V | LOAD=+5.2mA | OUTS | > 0.0V ; <0.26V  |
| IIH       | 6.0V | 0.0V  | 6.0V  | VIN = 6.0V  | INS  | >-0.1uA ; <0.1uA |
| IIL       | 6.0V | 0.0V  | 6.0V  | VIN = 0.0V  | INS  | >-0.1uA ; <0.1uA |
| ICCH      | 6.0V | 0.0V  | 6.0V  | VIN = 6.0V  | VCC  | > 0.0uA ; <4.0uA |
| ICCL      | 6.0V | 0.0V  | 6.0V  | VIN = 0.0V  | VCC  | > 0.0uA ; <4.0uA |

AC PARAMETRIC TESTS PERFORMED

| PARAMETER | VCC  | VIL  | VIH  | CONDITIONS | LIMITS @ 25°C    |
|-----------|------|------|------|------------|------------------|
| TPLHQ1    | 4.5V | 0.0V | 4.5V | CLK->Q1    | >2.0nS ; <29.0nS |
| TPHLQ4    | 4.5V | 0.0V | 4.5V | Q1 ->Q4    | >2.0nS ; <45.0nS |
| TPLHQN    | 4.5V | 0.0V | 4.5V | Qn ->Qn+1  | >2.0nS ; <15.0nS |

- Exceptions:
- 1/ VIH and VIL are tested during VOH and VOL testing.
  - 2/ A system capacitance load (approximately 35 pF) is placed on the outputs during AC tests in lieu of the 50 pF specified in the data book.

TABLE IV: Summary of Electrical Measurements After  
Total Dose Exposures and Annealing for M54HC4020YBF 1/, 2/

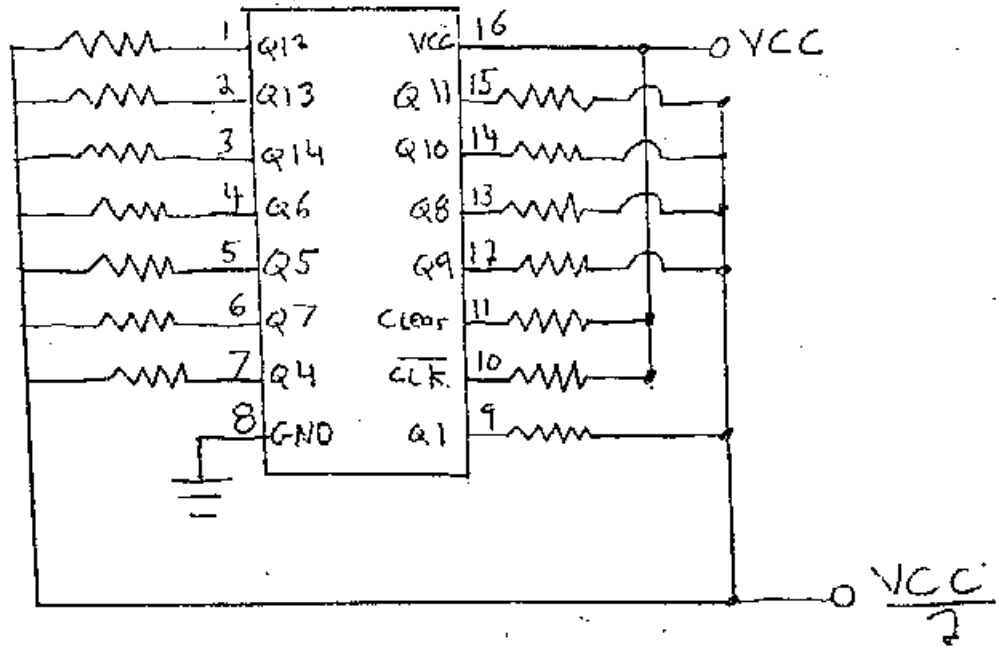
| Parameters            | Spec Limits<br>min max | Total Dose Exposure (TDE) (krads) |      |       |      |       |      |       |      |        |       | Anneal        |       |                |      |
|-----------------------|------------------------|-----------------------------------|------|-------|------|-------|------|-------|------|--------|-------|---------------|-------|----------------|------|
|                       |                        | (Pre-Rad)                         |      | 5     |      | 10    |      | 15    |      | 20     |       | 168 hrs @25°C |       | 168 hrs @100°C |      |
|                       |                        | mean                              | sd   | mean  | sd   | mean  | sd   | mean  | sd   | mean   | sd    | mean          | sd    | mean           | sd   |
| FUNC1 1 MHz           |                        | Pass                              |      | Pass  |      | Pass  |      | Pass  |      | 3 Fail |       | Pass          |       | Pass           |      |
| FUNC2 1 MHz           |                        | Pass                              |      | Pass  |      | Pass  |      | Pass  |      | Pass   |       | Pass          |       | Pass           |      |
| FUNC3 1 MHz           |                        | Pass                              |      | Pass  |      | Pass  |      | Pass  |      | Pass   |       | Pass          |       | Pass           |      |
| VOH1 2.0V V           | 1.90 -                 | 2.00                              | 0.00 | 2.00  | 0.00 | 2.00  | 0.00 | 0.50  | 0.87 | 0.00   | 0.00  | 0.00          | 0.00  | 2.00           | 0.02 |
| VOH2 4.5V V           | 4.40 -                 | 4.51                              | 0.00 | 4.51  | 0.00 | 4.51  | 0.00 | 1.13  | 1.97 | 0.00   | 0.00  | 0.00          | 0.00  | 4.50           | 0.01 |
| VOH3 6.0V V           | 5.90 -                 | 6.00                              | 0.00 | 6.00  | 0.00 | 6.01  | 0.01 | 1.75  | 2.76 | 0.00   | 0.00  | 0.63          | 1.85  | 6.00           | 0.02 |
| VOH4 4.5V V           | 4.18 -                 | 4.34                              | 0.01 | 4.34  | 0.01 | 4.34  | 0.01 | 1.08  | 1.90 | 0.00   | -     | 0.00          | -     | 4.32           | 0.02 |
| VOH5 6.0V V           | 5.68 -                 | 5.83                              | 0.01 | 5.83  | 0.01 | 5.84  | 0.01 | 1.94  | 2.78 | 0.00   | -     | 0.48          | 1.62  | 5.81           | 0.02 |
| VOL1 2.0V mV          | 0 100                  | 3.00                              | 0.09 | 3.00  | 0.09 | 3.01  | 0.08 | 2.99  | 0.09 | 3.00   | 0.10  | 3.06          | 0.11  | 3.46           | 0.35 |
| VOL2 4.5V mV          | 0 100                  | 2.93                              | 0.19 | 2.93  | 0.19 | 3.19  | 0.26 | 3.35  | 0.33 | 3.68   | 0.40  | 3.94          | 0.56  | 3.34           | 0.24 |
| VOL3 6.0V mV          | 0 100                  | 3.44                              | 0.37 | 3.44  | 0.37 | 3.76  | 0.47 | 3.99  | 0.55 | 4.38   | 0.63  | 4.88          | 0.96  | 4.11           | 0.43 |
| VOL4 4.5V mV          | 0 260                  | 109.5                             | 6.4  | 109.5 | 6.4  | 107.2 | 5.9  | 104.3 | 5.7  | 104.5  | 6.4   | 109.2         | 8.1   | 131.3          | 0.0  |
| VOL5 6.0V mV          | 0 260                  | 115.3                             | 8.1  | 115.3 | 8.1  | 113.9 | 7.4  | 111.3 | 6.9  | 112.6  | 7.9   | 117.8         | 10.0  | 135.9          | 0.0  |
| I <sub>IH</sub> uA    | -0.1 0.1               | 0.00                              | 0.00 | 0.00  | 0.00 | 0.00  | 0.00 | 0.00  | 0.00 | 0.00   | 0.00  | 0.00          | 0.00  | 0.00           | 0.00 |
| I <sub>IL</sub> uA    | -0.1 0.1               | 0.00                              | 0.00 | 0.00  | 0.00 | 0.00  | 0.00 | 0.00  | 0.00 | 0.00   | 0.00  | 0.00          | 0.00  | 0.00           | 0.00 |
| I <sub>CC</sub> uA    | 0 4.0                  | 0.03                              | 0.01 | 0.03  | 0.01 | 1.39  | 1.23 | 6.96  | 5.98 | 16.20  | 14.32 | 2.55          | 1.74  | 0.08           | 0.04 |
| I <sub>CC</sub> uA    | 0 4.0                  | 0.06                              | 0.02 | 0.06  | 0.02 | 1.76  | 1.16 | 14.59 | 8.37 | 308.1  | 119.3 | 110.3         | 106.3 | 6.87           | 9.37 |
| T <sub>PLHQ1</sub> nS | 2.0 29.0               | 14.50                             | 0.91 | 14.50 | 0.91 | 15.50 | 0.91 | 15.88 | 1.03 | 16.63  | 1.11  | 16.38         | 1.03  | 17.63          | 0.75 |
| T <sub>PLHQ4</sub> nS | 2.0 45.0               | 17.25                             | 1.04 | 17.25 | 1.04 | 17.88 | 1.11 | 17.88 | 1.11 | 18.38  | 1.11  | 18.50         | 1.23  | 21.25          | 1.66 |
| T <sub>PLHQN</sub> nS | 2.0 15.0               | 5.23                              | 0.79 | 5.23  | 0.79 | 6.01  | 0.82 | 6.35  | 0.87 | 6.61   | 0.86  | 6.56          | 0.79  | 7.11           | 0.87 |

Notes:

1/ The mean and standard deviation values were calculated over the four parts irradiated in this testing. The control sample remained constant throughout the testing and is not included in this table.

2/ The Post 10 krad measurements were made after one day of annealing at 25°C due to Automated Test Equipment problems.

Figure 1. Radiation Bias Circuit for M54HC4020YBF



$$V_{CC} = +5.0V \pm 10\%$$

$$\frac{V_{CC}}{2} = +2.5V \pm 10\%$$

$$R = 2K\Omega \pm 10\%, \frac{1}{4}W$$

$$T_A = 25^\circ C \quad 1^{st} \text{ annealing}$$

$$T_A = 100^\circ C \quad 2^{nd} \text{ annealing}$$



## APPENDIX A

The parts failed the VOH1 through VOH5 tests after 15 and 20 krads of exposure and after 168 hours of annealing at 25°C. The method used to perform the VOH tests is to condition all outputs to the logic high state and then measure the voltage on each output stage Q1 through Q14 with the specified current load applied to the output under test. In order to accomplish this test, first, all of the outputs are reset to the logic low state by setting the CLEAR pin high. Next, the CLOCK input is pulsed 16,383 ( $2^{14} - 1$ ) times with a 500 nS pulse with a 50% duty cycle. For a properly functioning part, this process would set all of the outputs to the logic high state.

From the logic diagram (Figure A1) for this 14 stage binary counter it is apparent that the external CLOCK input is used to toggle the first output stage, Q1. The complement of Q1 is internally connected to the clock input of the second output stage, Q2 and so on. A timing diagram for this microcircuit (Figure A2) shows that the fourth output stage, Q4, should toggle on the falling edge of every 8th CLOCK pulse which corresponds directly to every 4th falling edge of Q1. However, after 15 and 20 krads of exposure and the subsequent annealing at 25°C for 168 hours, it was observed that the Q1 output was unable to maintain a logic high state. This situation is illustrated in Figures A3 and A4. The inability of Q1 to remain high creates an additional clock pulse to the subsequent output stages with every CLOCK pulse input. Essentially, this problem makes this 14 stage counter appear to be a 13 stage counter (i.e. - the microcircuit counts through all combinations of its outputs after  $2^{13}$  CLOCK pulses instead of  $2^{14}$  CLOCK pulses).

The inability to maintain a logic high state is only apparent on the Q1 output stage. The reason that the other output stages appear to be failing the VOH tests is due to the additional clock pulse generated by the Q1 output stage. When the test program performs the VOH tests, it expects that the counter has been preset with every output in the logic high state. The extra pulse from the Q1 stage increments the counter from all logic highs to all logic lows, therefore creating the illusion that all of the output stages are failing VOH.

If you have any questions about this analysis, please contact Ted Scharer at (301) 731-8668.

APPENDIX A (CONTINUED)

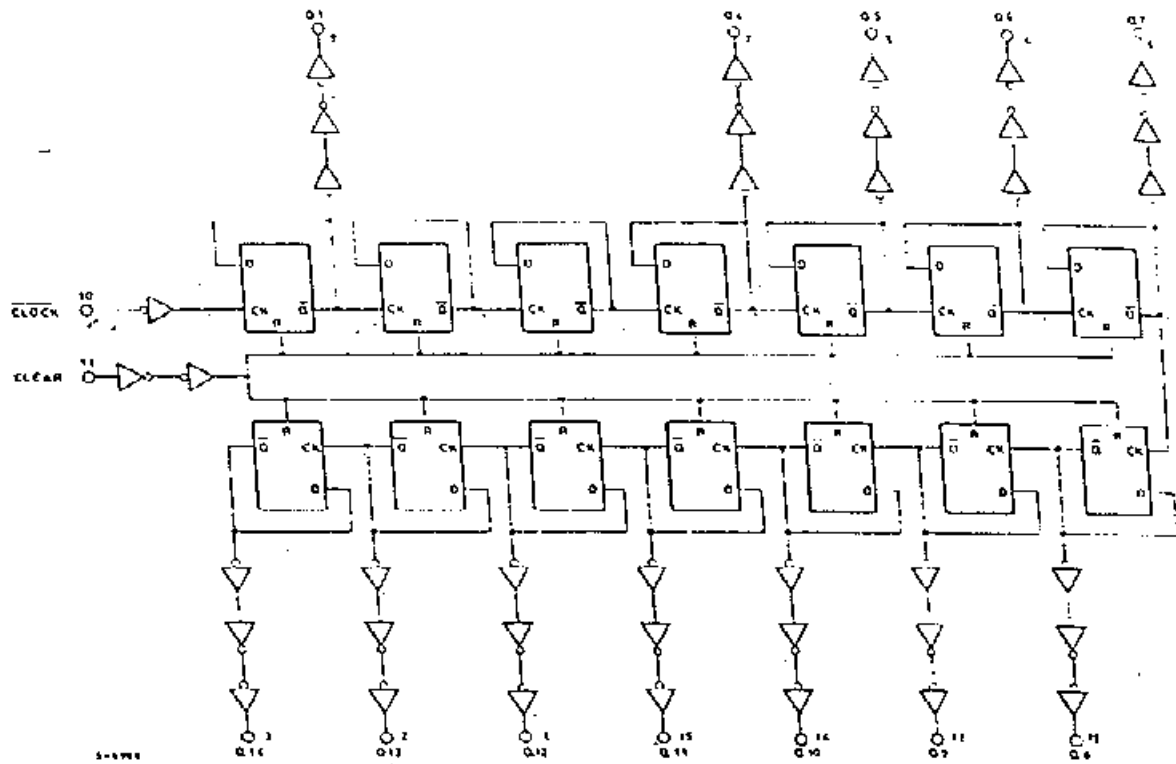


Figure A1 - Logic Diagram of MS4HC4020YBF

APPENDIX A (CONTINUED)

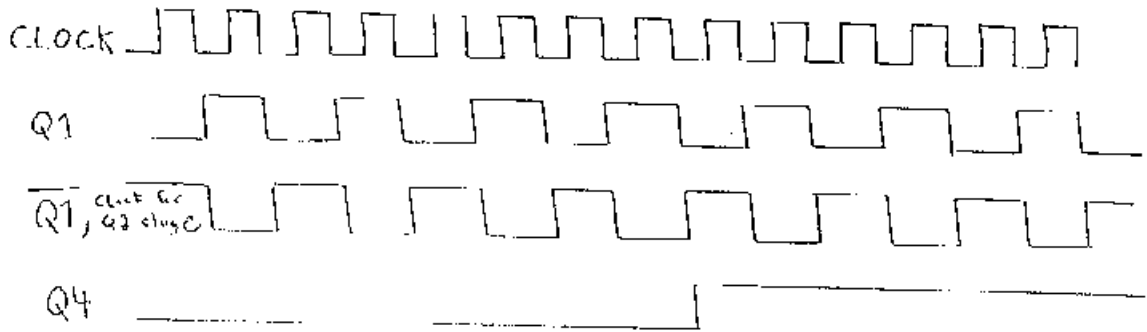


Figure A2 - Timing Diagram for a Passing Part

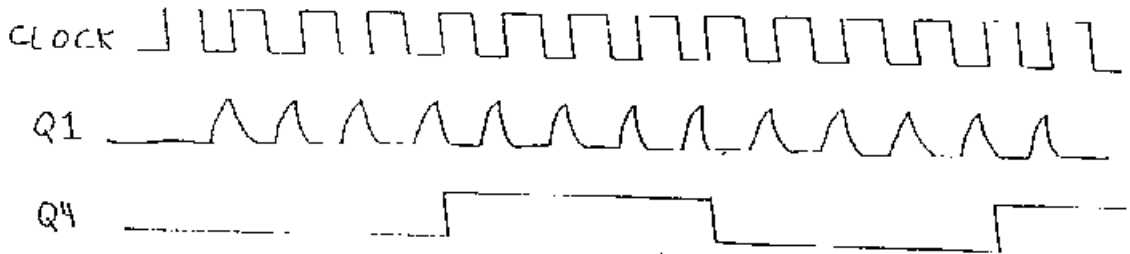


Figure A3 - Timing Diagram for a Failing Part

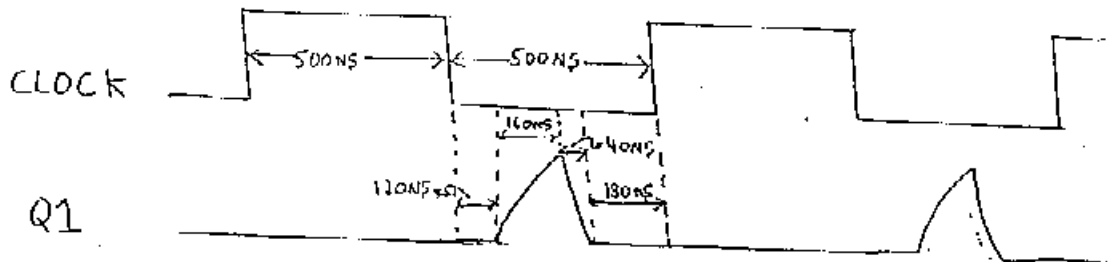


Figure A4 - Expanded CLOCK, Q1 Timing Diagram