Bendix

Aerospace Systems Division

Array E Action Item 604 -
Ripple on +5 volt line

NO.	REV. NO.
ATM-1098	

PAGE 1 OF 9

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ABSTRACT

Action Item 604 required an investigation into the apparently unique nature of the ripple on the Array E Qual Model PC #1 +5 volt output. This ATM shows that no fault condition existed and it provides a rationale for accepting occasional uneven ripple, within specification peak-to-peak limits, as normal PCU behavior.

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TABLE OF CONTENTS

LIST OF REFERENCES

Array E Action Item 604: - Ripple on +5 Volt Line

1.0 Introduction

Discrepancy Report DR AC 4126 (Reference #1) was originally written against all the outputs of the Array E Qual Model PCU, on the grounds that all the power-line ripple limits given in TP 2349002A were exceeded. Bendix Internal Memo 9713-507 (Reference #2) showed that the DR arose from an incorrect interpretation of the PCU specification regarding measurements at frequencies above 100KHz, and that only the +5 volt output of PC #1 was actually outside the TP limits. In addition, the TP limits were much tighter than the PCU specification limits, and, compared with the PCU specification, none of the ripple components were out of tolerance as far as overall system operation was concerned.

The only remaining problem, and the reason for Action Item 604, was the uneven ripple waveform on the Qual PC #1 +5 volt output, as compared with the regular ripple waveforms on all the other power lines of the Qual model, and on the two +5 volt lines of the DVT model. (See Figure 1). The uneven waveform was not in itself unacceptable, and it could not affect the system adversely, but in view of its apparently unique nature it raised the questions of the reason for it and whether it was indicative of imminent part failure.

This ATM describes the unsuccessful investigation into the possible causes of the uneven ripple on the Qual PC #1 +5 volt line alone, concluding with the discovery that the effect was not in fact confined to that line, and that it could then be theoretically explained by the combination of several randomly related contributary causes from throughout the PC.

2.0 Investigation

2.1 Figure 2 shows a simplified diagram of part of the converter transformer and rectification circuit. Since the original measurements apparently showed no uneveness on the +12 volt and -12 volt lines and since the +5 volt filter is common to both half cycles of rectification, the cause of the uneven ripple was assumed to lie at or between the points A, B and C. These parts of the PC circuitry are all contained within the Transformer/ Rectifier Module.

2.2 The obvious possible causes were: -

a. Transformer tapping error.

b. Unequal lead (printed circuit) resistances, due to geometry, badly soldered joints or a PC production fault.

c. Medium-impedance sneak path(s) to ground on one side, due to solder and/or PC whiskers.

d. Unmatched diodes.

Possibility (a), the tapping error, could be eliminated immediately, since it would have produced an imbalance approximately one order greater than observed.

Examination of the PC artmaster prints showed no anomalies.

A X20 magnifier inspection of the suspect Qual module, the Flight Module, and the PC boards intended for the spare module, revealed no hairline sneak paths or cracks. (The printed circuits on these particular boards are very simple and easy to check).

No soldering faults or whiskers could be seen, and in this respect it should be noted that all the soldered joints had already been inspected and passed by QA.

Unequal path resistances were ruled out, simply on the basis of the short lengths and the large cross-sections of the relevant PC leads. Although the resistances are without doubt not equal the levels of resistance which are involved are far too small to matter.

Having eliminated all other possible causes, only diode mismatch remained. Once the diodes have been incorporated into a module it is extremely difficult to measure the extent of any mismatch, but reference to the initial selection records showed that the whole batch from which the pair in question were taken had a very small spread, and that even if random interchanges between diode kits had occurred matching to within about 10 millivolts should have been retained.

There thus remained no possible explanation for the unique nature of the ripple on the Qual PC #1 +5 volt line.

2.3 As a part of the response to Action Item 604 the ripples on the outputs of the Flight, DVT and spare modules were examined, for comparison with the supposedly faulty Qual module. It was now observed that the Qual Model PC #1 +5 volt output was definitely not unique in having an uneven ripple waveform. It was undoubtedly worse than any other output in this respect, but depending upon the working conditions it was possible to produce similar uneveness on nearly all the other outputs.

Even the original photographs, upon which the Action Item was based, when re-examined closely showed traces of uneveness on the previously "regular" waveforms.

3.0 Conclusions and Suggested Explanation

3.1 It is now obvious that the problem is related to the overall operation of the converter, not to one specific module, and that there is no need to assume a fault in the Qual PC #1 +5 volt circuit, or anywhere else.

3.2 The ripple variations can be most easily and satisfactorily explained as the combined results of several random inputs. Being random, the net result would tend to a norm of zero (or at least small) i.e., even ripple half-cycle to half-cycle. Very occasionally, however, the contributions will have the same sign, leading to marked uneveness on the relevant output.

The possible contributary causes of uneveness are: -

(a) Different resistances in the two halves of the high-current converter input circuits - the printed circuit lines of the two halves differ by 60% in PC #1, but by only 10% in PC #2.

(b) Permissible 10 millivolt mismatching of the drops across the switching transistors.

(c) Slight differences in the turn-on, turn-off points of the switching transistors. This would affect the changeover characteristics, and it is noticeable that ripple uneveness at the converter frequency is always accompanied by marked inequality of successive RF ringing spikes.

(d) Residual magnetism in transformer care.

(e) Differences in coupling efficiency of the two halves of the primary and/or the secondary windings.

(f) Permissible 10 millivolt mismatching of the rectifier diodes at the nominal current selection point.

(g) Unmeasured mismatching of the rectifier diodes at the high current levels which are reached during the switching spikes. The transient working point could be far away from the average current level at which the diodes are selected, and could give rise to slightly different total charge transfers into the filter capacitor on alternate half-cycles.

This list is not necessarily exhaustive.

3.3 In order to measure the typical characteristics of each of these postulated sources of uneven ripple, and then to show that the observed final results are in keeping with the proposed explanation, a major research task would have to be set up. This is not justified in view of the facts that: -

(a) The ripple uneveness does not cause the overall system performance specifications to be violated.

(b) There is no longer any reason to suspect a possible part failure, which was the original major worry.

(c) Insufficient parts would be available to establish with any certainty the normal distribution for each parameter.

(d) The Qual Model PCU has by now run for many hours with no signs of deterioration.

4.0 Recommendation

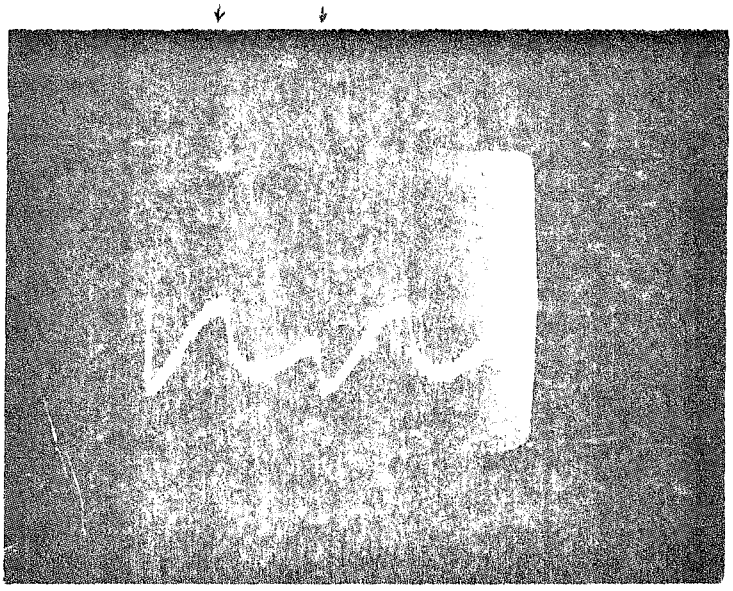
It is recommended that uneven power line ripple, half-cycle to half-cycle, of the type shown in Figure 1, be accepted as an occasional but normal characteristic of the PCU, provided that the maximum peak-to-peak ripple limits are not exceeded.

References

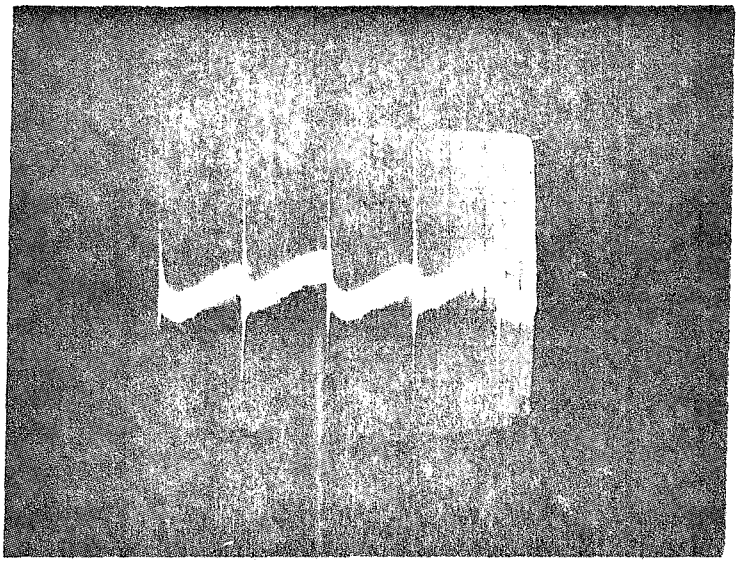
1. Discrepancy Report DR AC 4126 against Array E Qual Model Central Station. - Power line ripples exceeded TP limits.

2. BxA Internal Memo 9713-507, dated 2 February 1972, by C. Jensen. "Rationale for Clearing DR on PC Out of Tolerance Ripple Voltages - DR AC 4126."

Ripple Voltage



PC-1
5 VOLT line
20 mV/cm
20 μsec/cm



PC-2
5 VOLT line
20 mV/cm
20 μsec/cm

FIGURE 1

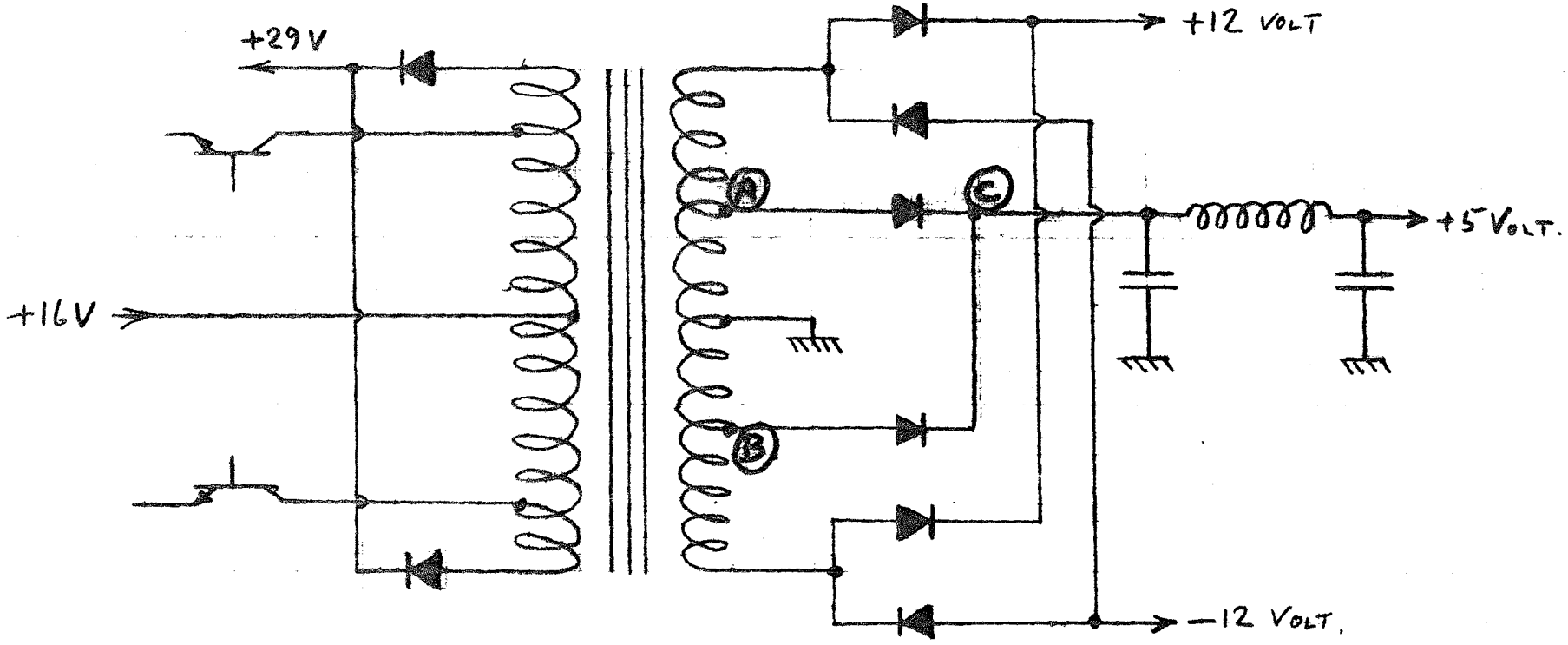


FIGURE 2: SIMPLIFIED TRANSFORMER AND RECTIFICATION CIRCUIT.