FAILURE ANALYSIS REPORT

MODEL : *EB24 and EBS2 Fluorescent Drivers*

CUSTOMER : *Aristocrat*

Date of Issue : *28-Aug-03*

Approved : *Peter Langford*
R&D Manager

SETEC Pty Ltd – 19 Henderson Dr, Knoxfield, 3180 Victoria, Australia. Phone: 61 3 9763 0962 Fax: 61 3 9763 8789.

Author: *Peter Langford - R&D Manager*

Fault Description:

CUSTOMER INFORMATION

Background

The customer has returned a quantity of 464 units for repair. 44 of these units were from one particular end use customer, and all failed shortly after shipment (these units will be known as the "X-cite repairs). These units were the basis for the failure analysis. Aristocrat was able to gather an additional 420 units from 3rd party repairers for analysis to further support the investigation.

Repair data

Setec repaired all units and the fault details are given below. For ease of analysis the faults have been categorised as follows

NFF = No fault Found
Q3 = Heating filament control mosfet fault
T1 = Main transformer Fault
C14 = Output resonant capacitor fault
other = miscellaneous fault

X-cite Repairs

	NFF	Q3	T1	Q3, T1	Q3,T1, C14	Q3, C14	T1, C14	C14	Other	Total Units
EB2413A Rev 06A	10	33								43
EBS2-13-T2 Rev 6A		1								1
Total fault types	10	34								44

3rd party repair units

	NFF	Q3	T1	Q3, T1	Q3,T1, C14	Q3, C14	T1, C14	C14	Other	Total Units
EB246A Rev 8 – 10A	5	5	88	14	16	9	0	0	10	147
EB246B Rev 05A	14	78	6	2	0	8	0	9	0	117
EB246B Rev 07A	14	59	3	1	0	2	0	5	1	85
EB246B Rev 08A	0	0	1	0	0	0	0	0	0	1
EB246B Rev 09A	8	2	2	0	0	0	0	0	4	16
EB246B Rev 10A	5	1	2	1	0	1	0	0	1	11
EB2413A rev 06A	1	8	0	0	0	0	0	0	0	9
EB2415A rev 05A	0	23	0	1	0	1	0	0	0	25
EB2415A rev 06A	0	6	0	0	0	0	0	0	0	6
EB2415A rev 08A	1	1	0	0	0	0	0	0	0	2
EB2415A rev 09A	1	0	0	0	0	0	0	0	0	1
Total fault types	49	183	102	19	16	21	0	14	16	420

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SETEC ANALYSIS

For the purpose of this analysis faults associated with Q3, T1 and C14 will be considered. The "other faults" consisted of a range of defects associated with handling, manufacturing and miscellaneous component failure and are therefore outside the scope of this analysis.

Q3 Faults:

Previous background to this component (refer Appendix B) showed a failure mechanism that occurred when operated with tubes exhibiting broken tube filaments. This was particular a problem with the T2 (thin) tubes. The 3rd party units show that a large percentage of these units 90% (166 out of 183) were early versions of the drivers subject to this problem. Revision level of product is given in Appendix A.

The remaining units showing faults with this device are mostly EB2413A's from both the3rd party and the X-cite units. Operation of this device was further investigated for component stresses. Tests revealed that all ratings were within device ratings for all modes of operation. These modes being continuos running and the fault conditions of EOL, broken filament, O/C, failure to strike and S/C tubes. A more detailed analysis of some of the fault modes is given below.

During the broken tube or failure to strike tube condition the mosfet is subject to the condition of "avalanche". This may also happen if the tube doesn't strike. During this condition the voltage from the resonant circuit reaches the fet avalanche voltage (~850V). Further investigation into the "avalanche" phenomenon was undertaken to rule out any problems associated with this, as there is some conjecture as to "ruggedness" of a device when subject to this condition. Mosfet's manufactures rate the avalanche energy with current flowing in the drain. This is to ensure that the avalanche current is evenly distributed across the device cells ensuring the current density/cell is maintained. Operation of the device in circuit is such that there is no drain current prior to the avalanche. Previous work in this area has resolved this issue by putting the proposal to the device manufacture. In this case the manufacture, ST Microelectronics inc has concluded that operation of their devices STP4NA80 and STP4NB80 within our circuit pose no problem for device reliability for the conditions assigned above.

Setec also carried out further investigations in an attempt to establish a failure mechanism. These are detailed below

a) Incorrect connection of cabling to driver: The two- way input connect for the input +24Vdc was forced into all possible insertions of the output four-way connector. This had no effect on the device. The rationale behind this test was to see if any part of the installation could cause damage. The X-cite units all failed immediately after shipment to end customer. So this raises the concern that there may be other external factors.

b) Avalanche testing: this was tested in circuit by simulating a broken tube (connecting the filament connections with 100R) and operating the driver continuously. This test operates the device in avalanche mode at frequency of 0.5Hz(real life condition). Additional accelerated tests at5Hz were also performed. These tests have been continually for the last 250hrs at the time of this report. No failures have been recorded.

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Avalanche testing was also conducted by simulating an arcing tombstone. This event can occur when the tube doesn't make a good contact with the tombstone and the tube current is interrupted. This was tested by duplicating these conditions and also simulating with spark gap arrangement. The later was required as the tombstone and tube contacts deteriorate after a minute or two of operation to the point where the arcing stops. This test was again trying to determine if external factors were influencing the failure.

c) Other component faults: by applying an intermittent open and short circuit to T1 output and C14 also causes the voltage of the mosfet to reach its avalanche voltage. These tests were conducted in light that some of the failures had both Q3 and C14 or Q3 and T1 faults.

For tests a), b) and c) no failure of any Q3 devices were recorded. No conclusions could be drawn as to why the devices have failed.

T1 Faults:
Faults of this component were mainly attributed to EB246A units of which there were 118. The fault is occurring at the lead out exits of the transformer secondary winding. The winding construction is such that the end of the winding coil is at 90' to the lead- in (which is perpendicular to the winding axis) for the winding start. Close inspection has revealing that lead-in wire insulation is breaking down pre-striking of the tube; the voltage climbs up to the region of 600V.

C14 Faults:
Operation of this device was verified for all modes of operation. Under no conditions are the component taken out of its rating.

Cause of Fault:

Q1 Faults: *90% of the failures are associated with early version drivers were there is a known fault. For the remaining 10% the root cause could not be established.*

However it must be noted that the 100% of the X-cite units had an even serial # distribution b/n 23xxx and 42xxx and all failed almost immediately at end use customer site. These units were delivered in a number of shipments from 9/8/2002 to 28/2/2003 and the one EBS2-13-T2 (s/n 300219) was shipped on 21/3/2003. This raises the question as to whether these failures are a result of handling or installation.

T1 Faults*: these are occurring due to insulation breakdown on the secondary at the winding start finish lead out. The reason for the breakdown is insulation damage. This can be attributed to wire quality, physical stress during the winding process, wire tinning (as heat from this process is in close physical proximity to the fault, ie heat travels up the wire and damages the insulation at the cross over point)*

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Note that the EB246B's and 13A's use triple insulated wire.

C14 Faults: *Root cause of fault not known.*

Actions:

Q3 Faults:
Setec are to send mosfets associated with X-cite repairs to manufacture for analysis of die. Further testing and evaluation of other sources will also be performed.

Aristocrat is to follow up on installation and operation of ballast within X-cite machines.

T1 Faults:
Setec are to review construction of T1 wire at cross over point for insulation robustness. This may involve changing wire to triple build or using extra insulation at this point.

C14 Faults:
Setec are to send components back to manufacture for analysis.

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APPENDIX A

Product Revision History

EB246A	
Revision	**Details**
01A	New product release.
02A	Introduction of three-section bobbin.
03A	Affix C-UR mark.
04A	Transformer secondary turns changed.
05A	Sleeving at the start of secondary of the transformer
06A	Changes to Label for UL
07A	Add Q3 series resistor.
08A	Change T/F details, secondary on bottom
09A	Updates for UL requirements
010A	Increase the strike voltage test limit. Include information on how to adjust freq in prod notes

EB246B	
Revision	**Details**
01A	New product release.
02A	Introduction of three-section bobbin.
03A	Affix C-UR mark.
04A	Transformer secondary turns changed.
05A	Sleeving at the start of secondary of the transformer
06A	Triple build wire on T1 secondary
07A	Changes to Label for UL
08A	Add Q3 series resistor.
08A	Change T/F details, secondary on bottom
09A	Change T/F run current, secondary on bottom, and pre-heat
010A	Increase the strike voltage test limit. Include information on how to adjust freq in prod notes

EB2413A	
Revision	**Details**
01A	New product release.
02A	Triple build wire on T1 secondary
03A	Changes to label for UL
04A	Add Q3 series resis tor.
05A	Change T/F run current, secondary on bottom, and pre-heat
06A	Updates for UL requirements

EB2415A	
Revision	**Details**
01A	New product release.
02A	Introduction of three-section bobbin.
03A	Affix C-UR mark.
04A	Transformer secondary turns changed.
05A	Sleeving at the start of secondary of the transformer
06A	Changes to label for UL
07A	Change PCB for added Q3 series resistor
08A	Change T/F details, secondary on bottom
09A	Updates for UL requirements

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APPENDIX B

EB246B Failure Analysis for Q3 and Broken Tubes: 26-Aug-1999

We have looked at our EB246B driver and found that a particular condition exists when operated with a faulty tube(broken filaments) where the device ratings on component designations Q3 can be taken outside their ratings. The mechanism which this occurs by is as follows;

When power is applied to the driver Q3 is turned on for the preheat time, that is, voltage is applied across gate source. There is no conduction path for the heat current through Q3 as open circuit filaments disconnect the device from the tube. The voltage across the tube (C14) is allowed to increase until ionization within the tube occurs. As this happens the filaments now conduct across their gap. Once this happens capacitor C14 is discharged through Q3 exceeding its current rating. Note that some of the current is also discharged across the tube, which is also conductive.

It must be stressed that the condition is variable due to a number of reasons. It depends on size of gap between each end of broken filament. If the longer end of filament is the one with the applied voltage, the amount of emissive material left on the filament. No two tubes with broken filaments are the same. However we have been able to reproduce the condition with one of the tubes that James Rist has supplied to us. (this one has both filaments broken). We have also been gathering data by breaking filaments (we are evaluating for either one or both broken filaments)

Note, when we duplicate the problem with one broken filament (given the right conditions), the discharge current path of C14 goes through the intact filament which may explain why sometimes both filaments have gone. Note it doesn't explain why the first filament is open!!

What normally happens is that the heating current flows through the tube filaments and the voltage across the tube is near zero during the preheat time. After the preheat time has elapsed, Q3 is turned off. This allows the voltage across C14 to increase (by virtue of resonance between L (leakage inductance of transformer) and C14.

The solution to this problem is quite simple, put a 100R resistor(pulse rated for the broken filament problem) in series with the mosfet to limit the peak surge. We have evaluated this and found there is no problems with pre-heat. At this stage I would suggest the following.

Clearly we will need to do changes to rectify this. Note, this problem occurs with broken filaments and tube intact.

Please note that this only necessary to protect the Ebxxxx from failure when operated into a faulty/failed tube. It is not necessary for normal operation.

We would like to raise and EC and MA for the EB246B driver effective immediately.

For the other tube drivers and the data at hand, we believe this is not as big a problem as tubes are not failing in the same manner as those used with the EB246B driver. Note that the value of capacitor C14 in the other drivers is half that of the EB246B and thus the energy is half in the discharge pulse.

Also the question needs to be asked of OSRAM why filaments a failing in the first place.

Note, original article had reference to EB246A, this has been corrected to EB246B.

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