Test Report

FLASH Failures in the MSP430F1611 Microcontroller

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# Introduction

There have been a small number of reported failures (approx 4 out of 452) in the ELC’s for the Playworld Drive-Away and Animal Tunes products that have rendered the devices non-functional. It was observed that simply reprogramming the units with the Playworld Production Programmer Utility would repair the unit and it would function normally. Once it was discovered that reprogramming the units fixed the problems, units that exhibited this problem were investigated in more detail before being reprogrammed. Using the FET-Pro430 software utility from Elprotronic Inc., the FLASH memory contents were compared against what is programmed at the factory. It appeared that approximately 90% of the FLASH memory had been corrupted and/or erased (reset to 0xFF). There did not appear to be a specific pattern to what FLASH locations were corrupted as errors seem to be evenly distributed across the FLASH page. After researching the problem in published Texas Instruments’ application notes, datasheets and support forums it appears that the overwhelming majority of FLASH corruptions happen when there is a power failure and the microcontroller is trying to reprogram FLASH in system. The firmware for the Drive-Away and Animal Tunes products never writes to FLASH.

There have been reported in the user forums of FLASH corruption if the device power is not clean and does not rise to its target potential in a timely manner. There were several posts on the TI E2E forum concluding that if the power supply to the chip has a very slow/noisy ramp up from 0 volts to the target voltage (+3.3v in this case), there is the possibility that the chip will execute random code which may accidentally erase flash. For FLASH memory to be erased programmatically, the CPU would have to jump to random code that just happens to go through the exact sequence to change memory. The sequence of events to change memory requires a lot of effort by a programmer and is unlikely to happen randomly. While this case seems unlikely, it is something that can be tested.

The circuitry used for the MSP430F1611 was sent to Tim Love (support@ti.com) who is a MCU application engineer at Texas Instruments. He did provide some suggestions to try to induce the failure, but saw nothing out of the ordinary in the design that could cause a failure. Figure 1 shows the power supply circuitry used for both the Drive-Away and Animal Tunes microcontroller section.



Figure : MSP430 Power Circuitry

The analog and digital power supply pins are both decoupled according to TI recommendations. The reset line is pulled high and loaded with a 10000pF capacitor according to TI specification. The +3.3v regulator used has a 0.1uF bypass cap and a bulk 10uF capacitor to provide smooth power rails. Note that the +5v power is supplied by a LM5574 based switching regulator circuit which is shown in Figure 2.



Figure : 5v Regulator Circuit

The “+5V\_IN” port of the circuit in Figure 2 ties directly to the “BRAIN\_+5v\_IN” port in Figure 1. The “+5V\_IN port” is tied to a large 47000uF capacitor. The capacitor is charged via a brushed DC permanent magnet motor whose output is bridge rectified and applied to the capacitor. The LM5574 can regulate to +5v from about 7v to 70v. As the circuitry in the Drive-Away uses energy, the charge in the capacitor drops. Once the capacitor voltage is around +7v, the 5v rail turns off which then turns off the +3.3v line to MSP430. The input circuitry is shown in Figure 3. Note that the port “RECTIFIED\_OUTPUT” in Figure 3 is tied to the port “+5V\_IN” in Figure 2. The 47000uF capacitor is not shown in the circuit drawings and is connected from “RECTIFIED\_OUTPUT” to “GND”



Figure : Power Input Circuitry

The primary power source of the circuitry is a DC permanent magnet brushed motor/generator. A user will turn a mechanism which turns the armature of the motor. When the motor is rotating, it produces a DC potential. The potential produced can have significant noise superimposed on the output. The 47000uF capacitor and small bypass/decoupling caps do a very good job in filtering any noise in the supply lines. There are sensitive audio circuits in the design, and no audible noise can be heard from the operation of the motor. It has been observed that a significant amount of EMI is produced by the motor. In some cases it is particularly bad if there are bad brushes/contacts in the motor. In high torque, high velocity scenarios, the brushes make contact with the rotor thousands of time per second and generate EM transients. This EMI may be linked to the FLASH failures.

# FLASH Failure Tests

To fix the FLASH corruption problem, several tests were developed to try to programmatically induce the problem. The goal is to find a test that can stimulate the problem on demand. The following sections describe the tests.

## DC Brownout at MSP430 Power Rails

This test tried to simulate a low voltage brownout condition at the MSP430 +3.3v supply rails. The MSP430 firmware was verified with the Elprotronic FET-Pro430 utility before and after the test. Three different brownout potentials were applied to test point T8 shown in Figure 1. The power was supplied via BK Precision 9110 DC power supply.

Results are shown in Table 1.

|  |  |  |
| --- | --- | --- |
| **Power Supply** | **Test Time** | **Result After Test** |
| +1.7v | 8 Hours | FLASH OK |
| +1.0 | 8 Hours | FLASH OK |
| +0.8v | 8 Hours | FLASH OK |

Table : DC Brownout Test Results

## AC Brownout at MSP430 Power Rails

This test tried to simulate a continuously varying supply that ranges from -0.5v to +4v. The HP 33120A function generator was used to provide the supply excitation to test point T8 shown in . The output impedance is low (50) compared to high input impedance of the MSP430. Only a couple mA of current is required to operate the MCU so the function generator could used as a suitable source. The function generator was placed into triangle wave mode. Two different frequencies were used for excitation: 2Hz and 30 Hz. The amplitude and offset were adjusted to produce the waveforms shown in Figure 4. Notice the distortion in the output waveform due to the dynamic input impedance of the MSP430F1611.



Figure : Triangle Wave Supply Excitation

These waveforms represent unfavorable power conditions directly to the microcontroller power pins. Results are shown in Table 2.

|  |  |  |
| --- | --- | --- |
| **MSP430F1611 Power Supply** | **Test Time** | **Result After Test** |
| 30Hz Triangle: -0.5v to 4v | 8 Hours | FLASH OK |
| 2Hz Triangle: -0.5v to 4v | 8 Hours | FLASH OK |

Table : AC Brownout Test Results

# Conclusion

Simulating brownout and poor power conditions at the microcontroller port pin did not induce FLASH corruption in these experiments. It is possible that the issues are still power related, but the system dynamics cannot be easily replicated with a bench top experiment that excites the power pins of the microcontroller directly. Future experiments will try to induce the failure by incorporating the other system components such as the DC motor/generator and large 47000uF capacitor. This approach might provide a better model to induce failures.