

The Trailing Edge

June 2024

I Have an Electromagnetic Interference Problem – Please Schedule the BAF

As a young kid learning about electricity, all that mattered was Direct Current, or, as the cool kids said, DC. Alternating Current, or AC, was what came out of the wall, and was used to turn on the lights and to be rectified into DC. Power supplies were batteries or rectified AC, and were used to run toys, like model trains.

At a frequency of zero, DC had to travel through wires, and thus could be kept under control. Yes, even DC current creates a magnetic field, but that magnetic field is constant and thus doesn't propagate. Electro-Magnetic Interference (EMI) was a weird, unexplainable phenomenon that happened by magic. It was something you just lived with, like how when you turned on the vacuum cleaner, the television was scrambled and unintelligible. It really didn't matter, since the vacuum cleaner was so loud you wouldn't be able to hear the TV anyway.

EMI occurs when the source has some type of alternating or rapidly changing current causing the circuit to act as an antenna generating an electromagnetic field. This electromagnetic radiation passes wirelessly through the ether or through the wires to the victim, which acts as an antenna receiving the radiation, which is then converted into some undesirable output.

What The F*, Over?**

Modern aircraft have so many different avionics and other electrical equipment in them that the practical question is not "IF" there will be electromagnetic interference in the system as a whole, but rather "WHERE" is that EMI going to manifest itself?

In the case of my Bearhawk "Three Sigma", the first case of EMI manifested itself quite by surprise during the Phase I flight testing. While flying over Apple Valley airport on autopilot, I keyed the radio to trigger the broadcast of current weather conditions from the airport. Each time I keyed the radio, the autopilot responded with an aggressive uncommanded pitch up. When I released the radio key, the autopilot responded with an aggressive pitch down back to the set altitude. That's something that will definitely get your attention, but that's not the EMI story we are covering in this missive. That story has already been covered in detail at <http://eaa1000.org/1107nltr.pdf#page=4> and <http://eaa1000.org/1108nltr.pdf#page=2>. The short answer was the EMI was defeated by shielding the autopilot control box.

Dealing With Range Anxiety

I developed range anxiety at a very young age, when I learned that the battery life of cheap carbon-zinc dry cells in a motorized toy car was about five minutes. While building my Bearhawk, the options for music entertainment changed from cassette tape players and CD players to this newfangled device called an iPod. It could hold my entire music collection and play all of it in any order, but it ran on a battery. This battery would eventually run out of trons, rendering the iPod useless. Therefore, I set out to make sure my Bearhawk had sufficient power sources to cover each crewmember individually. On the panel holding the headset jacks, each crew station was equipped with an input jack to play an iPod through the headset audio. Of course, only one station could be used at a time in the front seat and one station in the rear seat, but the point was that the music could originate from any crew station.

To support these iPods, each crew station was equipped with a power outlet. A typical car cigarette lighter socket was much too large for this application, so a small socket for a barrel plug was installed. This socket only had a current capacity of 500 mA, or half an amp if you prefer those units. This current was sufficient for charging early iPods. Originally, the barrel plug was to be wired to a Firewire cable, which plugged into an adapter from Firewire to the Apple 30 pin plug. This worked because Firewire carried power at 12 volts. At some point, the power connector for the iPods and the iPhone changed from the 30 pin plug to the Lightning plug. Since the Lightning cables carried power at 5 volts and used wires too fine to modify, I created a cigarette lighter socket wired to a barrel plug. Into the socket went a cigarette lighter USB adapter of the type that was becoming ubiquitous at the time.

Roll Your Own Data Acquisition System (DAS)

As a career Flight Test Engineer, I knew that I would want to do flight test on my Bearhawk. While I am a big fan of “Handheld Data”, it’s nice to have a way to automatically record the data while I am flying. The JP Instruments EDM-900 Engine Monitor was equipped to record all of the engine data every two seconds, or a data rate of 1/2 Hertz.

The Dynon D-10A EFIS did not record data, but it would output serial data in real time. These data included airspeed, altitude, heading, attitude angles, vertical and lateral accelerations, and turn rate. Data were output at 64 Hertz.

The Garmin GNS-480 GPS did not record data, but it would output serial data in real time. These data included latitude, longitude, ground track, ground speed, and course data. Data were output at a variable data rate between about 100 Hz and 256 Hz.

In order to record the EFIS and GPS data, the EFIS and GPS were connected to the COM1 and COM2 serial ports on a laptop computer. I wrote a program in Visual Basic 6 to record the serial streams in real time. Additionally, an audio recording program recorded the headset audio through the microphone input.

However, the laptop doing all of this recording needed ship’s power to ensure its battery would not go flat during the flight. How to supply this power? The previously mentioned power outlets were insufficient with only 0.5 Amps available.

“Airplane” Power Outlets

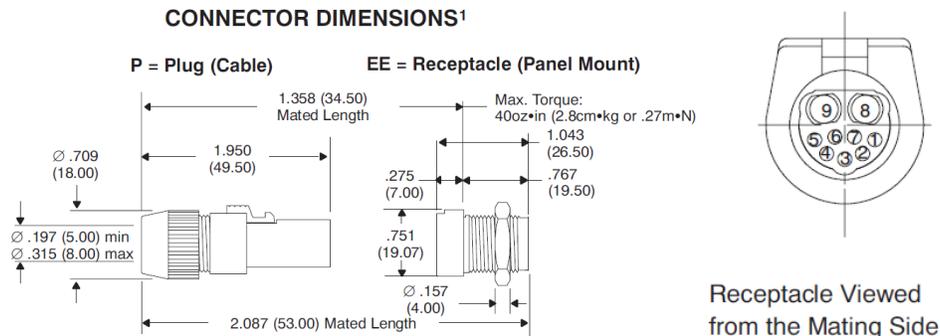
In the ‘80s, the desktop computer became available and rapidly improved. In the ‘90s, there was a move to make the computers smaller and more portable. This would result in the development of what we now know as the laptop computer. With portable computers available, more and more people were interested in taking their computer with them while travelling. Battery technology was limited to nickel cadmium (NiCd) or nickel metal hydride (NiMH), and most laptop batteries lasted about an hour, maybe two if you were really lucky.

As such, there was a demand for external power available at an airliner seat. Some airlines responded by installing power outlets for passengers, though probably only in First Class and Business Class. I heard about them but never actually saw one at my place in the cheap seats. It was not clear at the time how to best do this, so the airlines did not do what would seem obvious and provide a standard 110 VAC outlet, probably because they would need inverters to create the 110 VAC, and 28 VDC was already readily available. Instead, the airlines provided power through ARINC 628 DC power connectors. After all, ARINC 628 was an aviation specification, so what could go wrong? These connectors were rated to deliver 8 amps of current, which would be 96 watts at 12 volts or 192 watts at 24 volts.

The only problem with the airline’s plan was that power supplies with ARINC 628 inputs did not come with laptop computers. If they existed, they were a separate purchase, which means a buyer would have to expect to use it a lot to make it worthwhile.



ARINC 628 Connectors



ARINC 628 Connector Dimensions

By the 2000s the plethora of electronics power connectors made the Wild West look civilized. Every device had a different power connector. Because the wall-wart power supply carried the name of its manufacturer and not the

name of the device it powered, it was really easy to forget what power supply went with what device. A company called “Juice” attempted to address this problem with a single power brick that would be all things to all devices, having changeable power tips so that you could get it to work with each of your devices, from iPod to phone to laptop. The power inputs to the power brick included 110 VAC, a 12 volt cigarette lighter plug, and an ARINC 628 plug for those airline trips. I bought one of these systems to power my laptop in the Bearhawk. Gary Aldrich found a source for ARINC 628 plugs and sockets. I installed an ARINC 628 socket in the instrument panel to provide 12 VDC power. I used the ARINC 628 plug on the Juice system to plug the power brick into the airplane, which then powered the DAS laptop. The ARINC 628 socket was on a 15 amp circuit with 16 AWG wires, so plenty of power was available for the laptop or anything else.



ARINC 628 Socket Installed in Panel

This setup was used to power the laptop DAS for the First First Flight on 7 June 2008 and on the Second First Flight on 11 June 2008. The system worked as designed. (How do you have more than one First Flight? It doesn't count as a completed First Flight if you have to land because of an in-flight emergency.)

The Second First Flight ended early because of severe engine overheating. The engine was removed, torn down and rebuilt. The Third First Flight did not occur until 8 May 2009. In the intervening time, several changes occurred.

Dynon released a software update that enabled the D-10A to record data internally. Data were recorded at a rate of 1 Hz for two hours in a circular buffer, meaning that after two hours the new data over-wrote the oldest data in the buffer. In addition to recording the data that the D-10A made available on the serial output, it also recorded the GPS data that were connected to the D-10A, which the D-10A used to calculate winds and display GPS course data on an HSI presentation. The result was that the external recording of data on the laptop DAS was now redundant and unneeded. This was just as well, because the laptop I was using failed, and I replaced it with a Windows 7 netbook. Windows 7 was incompatible with software written in Visual Basic 6, so the recording software I had written was no longer useable. Since the laptop DAS was now non-functional and not needed, there was no longer a need for the ARINC 628 power outlet.

Time to Shift Your Paradigm

Because of lack of availability on the consumer side and limited functionality, adoption of the ARINC 628 standard for powering laptop computers never really took off (insert your own airline joke here). Eventually airlines would replace their ARINC 628 sockets with sockets supporting 110 VAC, USB, and several other power formats. When all of the customers had their own phone or tablet for entertainment, the airlines realized that it was far cheaper to provide power outlets and WiFi than to build and maintain in-flight entertainment systems, so power outlets appeared at all seats, including Economy. With no market left, availability of any sort of ARINC 628 plugs dried up.

For years I looked at that ARINC 628 socket in the Bearhawk and thought about how I could restore the availability of higher amperage power while in flight. In the intervening times, power supplies for devices had become far more civilized. Universal Serial Bus (USB) had become the new standard. The USB specification included power, which was originally limited to 500 mA. Later versions of the USB specification increased the power available. There was a major surge in purchase of power supplies when tablets like the iPad became available, requiring at least 2.1 Amps. In an effort to tame the number of discarded power supplies, the European Union (EU) declared that power input for devices would standardize on USB. Some devices started with mini-USB, but the majority switched to micro-USB. Meanwhile, Apple had developed their own proprietary standard in the Lightning connector. Eventually, Apple gave in, and pretty much everything now is powered by USB-C. With the introduction of the USB-C Power Delivery (PD) specification, high power was now available for large devices such as laptops and tablets. Power was available in multiple combinations, including 5V/2.4A, 9V/3A, 12V/3A, 15V/2A, and 20V/3A (60W).

Thus, the power landscape changed from bespoke power adapters (wall warts) for everything to everything using USB power supplies. This has become so prevalent that some products reduce their cost by shipping without a power supply, since they assume you already have a bunch.

As the prevalence of smoking declined, both for known health effects and declining social acceptance, the “cigarette lighters” in cars remained, but were renamed “power points”. Rather than depend on adapters to plug into power points to provide USB sockets, a market arose for replacing cigarette lighter sockets with devices with USB-A and USB-C PD sockets. These devices were designed to fit in the form factor of the cigarette lighter socket, so they

tended to be roughly the same size. These allow the user to plug in their devices using the power cord that came with the device.

Power Upgrade for the Bearhawk

Since the ARINC 628 power outlet was effectively useless, in November 2021 I undertook a project to replace it with a high power USB-C outlet. I purchased from Amazon an AlfredDireck Quick Charge 4.0 PD Type C and Quick Charge 3.0 USB Charger Socket.

This socket only required 12 volt power and ground wires, so I could use the same wiring harness that powered the ARINC 628 outlet. However, the socket was significantly bigger than the ARINC 628 socket. There was room for the new socket within the structure, but it would spread outside the boundary of the "Flight Test Instrumentation" area. I solved this by designing and ordering a new panel from Front Panel Express (<http://frontpanelexpress.com>). This panel was applied to the old panel, covering up anything that didn't look right and making it look intentional.

The new socket was installed by rough cutting the hole with a drill and coping saw, then filing the old panel to match the hole in the new overlay.



Who Needs an EMIC?

The new power outlet was wired into the wiring harness used by the ARINC 628 connector. Ground testing consisted of applying power and plugging in sample loads to the power outlets. The USB-A socket successfully charged an iPad. The USB-C PD socket successfully charged my new laptop computer. There was no reason to think that I needed to do an Electro-Magnetic Interference Check (EMIC) (though there should have been).

At some point I decided to do an in-flight test of the new power outlets. While flying, I plugged an iPhone into the USB-A outlet and it charged just fine. Then I plugged my laptop into the USB-C PD outlet and all heck broke loose! Immediately there was a very loud and annoying static noise in my headset. I unplugged the computer and the noise went away. I plugged it back in and the noise returned. I unplugged it again and decided that this was something that needed to be investigated on the ground.

Back on the ground, I confirmed that the results could be replicated. Without having to worry about maintaining aircraft control, I was able to determine that the noise was coming from the GNS-480 VHF radio. When the USB-C PD socket was in use, it was causing the VHF radio to break squelch and produce loud static.

I did not take immediate action, since I didn't have a need to use the USB-C power in flight. I merely avoided using it.

In May 2024, I decided to reattack the problem. The autopilot EMI problem had been solved by shielding the control unit, so I thought that might work this time. I pulled the socket out of the panel and wrapped it in aluminum foil to test the theory. Plugging in a load caused the same loud static on the VHF radio as before.

Having used up my one idea, I started to head home. Then I realized that I had another USB-C PD power supply plugged in the cigarette lighter socket of the car. I brought that to the airplane, used some jumper wires to connect it to aircraft power, then plugged in a load to the USB-C PD socket. Checking the same VHF radio...nothing. No response. No breaking squelch. Apparently, my problem was local to the USB-C PD socket I had installed in the airplane, and not common to all USB-C PD power supplies.

Now totally confused, but somewhat encouraged that there might be a solution, I headed home and sent this story to my go-to Electrical Engineer, Randy "Kanard" Kelly. I said I thought it was weird that a power supply could interfere with a VHF radio. He responded "Plugging something into a USB-C port and having the radio unsquelch SOUNDS weird, but actually isn't weird. USB-C, unlike USB-A, is designed to carry video signals as well as audio, which is a much higher frequency. Something that just used USB-C to get power wouldn't be a problem, but anything that was expecting to be providing high speed data/video to another device would feed that high frequency back to the port. (iPads and iPhones will output high speed/video data). If that RF "couples" back to the power lines in the converter then you're feeding RF back to anything else on the bus. Shielding the unit with an RF "shield" (aluminum foil) won't provide any protection. You'd have to put an "RF choke" on the input power lines.

The "trial and error" method works OK for "routine" EMI checks. The problem is the cheap chargers may all use the same sources for parts. This may be a situation where you actually save yourself a lot of time by buying a USB charger system designed to go in an aircraft. You might try finding a charger designed to go on a motorcycle as the newer motorcycles have a lot of electronics and any "add on" chargers may need some shielding. Motorcycle parts also tend to be expensive, but not as much as airplane parts."

I found there was truth to what Kanard said, as I went to the Aircraft Spruce web site to see what they had for USB power outlets for aircraft. The first thing that popped up was the Appareo Stratus for only \$399. The price itself was a big problem. It was also a different form factor, so it couldn't go in the old hole where I wanted it. However, it was interesting that in the product description was this: "No Radio Noise. Stratus Power is radio-shielded, so you won't experience NAV/COM interference like you do with cheap electronics." Apparently, I was not the first person to have this problem.

Risk Managing Possible Solutions

Someone (probably Stormy) once told me "When trying to solve a problem, start with the cheapest solution first." While getting an "aircraft" solution like the Stratus had a high probability of working, the cost to buy one was excessive, especially considering I did not have a validated requirement to plug into this thing in flight.

I decided to try ordering up to a few other brands of power outlets from Amazon to try. My risk analysis included these points:



1. Testing the cigarette lighter USB-C PD adapter showed that there was a significant probability that a low-cost commercial solution was available.
2. All of the many power sockets on Amazon cost less than \$20.
3. If it didn't work, Amazon has a no-fault return policy.

I searched Amazon, looking for a power socket of a different brand. They all seemed to be the same diameter, probably because they are all intended to replace cigarette lighter sockets. Thus, there was a good chance that it might fit in the existing hole in the panel. I read carefully for any comments on radio interference. I also looked at the power output, since some only output 1.5 or 2 amps, while others output 10 amps. I selected a Thievel 12V Type C USB Outlet Quick Car Charger. It cost the princely sum of \$14. I ordered it, and it arrived the next day.



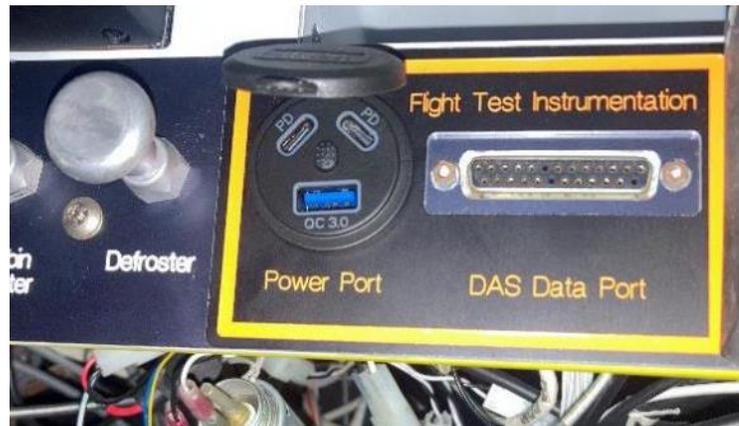
When I compared it to the previous power socket, they were the same diameter, but very different in length. This encouraged me that the new socket had different electronics and was not just the old socket rebranded to a different name. They were indeed the same diameter, as the attachment nut of the new socket fit on the old socket.

The new power socket fit the same wiring harness as the old one. This socket had an ON-OFF power pushbutton switch in the middle. The blue labels glow when the power is ON, and turn off when the power is OFF.

I connected the new power socket to aircraft power, turned on the VHF radio, then plugged a load into the USB-C PD power outlet, and...nothing! There was no response from the VHF radio when the USB-C PD was providing power. A successful ground test.

With this success, it was time to install the socket in the panel. Would it fit in the same hole? In a word...no. In another word...almost. The flats on the side of the case were slightly smaller than the flats on the old socket, meaning the case was slightly larger. Using a file, I filed off an estimated 0.020 inch on either side of the hole and the socket slipped in.

Flight testing had the same results as the ground testing. Both USB-C PD ports were connected to charge a battery and then to charge a laptop. At no time was there any response from the VHF radio or any other system. The USB-A port likewise was hooked up to an iPhone with no response from any other system. Flight testing also confirmed that the sockets provided no power when the power switch was in the OFF mode. That wasn't specifically on the test card, but some things just become known.



The power port was now available for use in flight for any purpose, such as powering a second iPad or EFB.

About That Article Title

At TPS our students are taught about electromagnetic interference in the Mission Systems curriculum, and how one system may affect another system undesirably. To check to see if this is a problem, we do an Electro-Magnetic Interference Check (EMIC). We teach them that an EMIC is basically just turning on one system (the victim), then turning on another system (the source), and determining if there is any undesirable effect on the victim system. This can be done anywhere, but generally is done as a ground test. IF there is a problem, it may be necessary to put the aircraft in an electromagnetically quiet environment, such as the Benefield Anechoic Facility (BAF), to confirm that the problem is really from the source system and not something else in the environment. Somehow, virtually all of the students incorrectly come to the conclusion that any EMIC must be done in the BAF. However, they never catch on to the fact that the BAF is heavily scheduled (not available for months or years) and very expensive to setup and operate. Hence the joke that I have an EMI problem, so I need to schedule the BAF.

- Russ Erb