# Common causes for EFIS system issues in aircraft installations and their fixes

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This document discusses common causes for issues affecting the reliability of electronic instruments in aircraft installations and their remedies.
In particular this document is directed at complex EFIS systems but is very generic in nature.

Complex EFIS systems (as apposed to simple EFIS systems) form the central node of many interconnected systems and due to its position from an electrical point of view is vulnerable.

EFIS malfunctions can range from simple, intermittent software issues to “crashes” or “hangups” to physical damage of the system.

EFIS systems tend to be designed to the environmental requirements sent out in DO-160. However, for the most part these requirements assume a well designed system in a typical aircraft. Incorrect installations can exceed the limits imposed by DO-160 by a very significant margin.

## *The power supply*

The EFIS power supply is perhaps the largest root cause of intermittent problems. Proper design and verification of the power supply design and installation have to be performed. At a very minimum it is required to test the power supply system during ground and flight operations using an oscilloscope which will immediately show any issues. Typical issues range from short dropouts for example when other high current loads are switched on to contamination by RF during radio transmission to grounding related issues (ground faults).

We have measured RF amplitudes in excess of 40Vpp on the power supply to an EFIS system in one particular case due to poor wiring techniques. This is highly damaging as no common power supply system can regulate fast enough and filtering has limited effectiveness without external assistance. Typical effects in minor cases: EFIS may show incorrect readings during transmission, for example incorrect airspeed or vertical speeds etc. Sensitive sensors tend to be affected first.

## *Static discharges*

Should your aircraft have any metal or other conductive surfaces such as carbon fiber parts that are not electrically connected to a common ground (airframe ground point), there is great danger of static discharges in the form of small but powerful “lightning” bolts or corona discharges. This is caused by airflow over these areas which charge these sections to many thousands of volts until a discharge into the aircraft ground or wiring is forced. This is more

prevalent in conditions of low humidity and may “go away” when humidity is higher creating further difficulty for locating these problems. Note that similar issues can be caused by electrically isolated parts of the engine installation.
Discharges cause a severe effect on the EFIS power supply which can result in malfunction. Proving and locating issues can be difficult but here are some basic pointers:
Use a simple ohm meter with one end connected to ground and the other with a long lead. Identify any possibly isolated metal or conductive parts and ensure conductivity to ground.
Use a simple long wave receiver (AM radio) tuned to an arbitrary but quiet frequency to listen to discharges (these cause a crackling sound) with the engine running. In severe cases, consider connecting the audio output to the aircraft's intercom system so you can listen in flight.
Discharges involve very large current flows for a brief time. Depending on your wiring – this can provoke large voltage spikes on your EFIS power supply. Discharge directly into a signal or control wire can prove damaging to the connected equipment.
For engine related discharges we found running the engine at night with cowling removed quite effective – the discharges are very visible when it is dark. We found a case where discharges happened around a radiator which was installed using isolating rubber mounts – a quick earth strap around one of the mounts fixed the problem. The discharge energy found its way into the instrument via the engine temperature sensors.

## *Temperatures*

One of the most ignored installation issues are temperatures behind aircraft instrument panels. EFIS systems, like all electronic devices are limited to temperatures ranges the electronic devices can operate under. Extreme high or low temperatures can easily exceed these limits resulting in lower life expectancy of the electronic components or component damage. Thermal stresses can also physically damage electronic assemblies. One of the more common types of related damage are intermittent contacts due to broken solder joints.
We have measured temperatures approaching 100 degrees Celsius inside our instruments caused by extreme “behind the panel” temperatures. These temperatures can easily be created due to complete lack of airflow behind the panel. Combined heat from various electrical devices plus heat from sunlight on a hot summers day rises behind the panel and has nowhere to go – it just keeps getting hotter. Electronic devices, in particular those controlled by computers do not like this can can simply stop working. Most “extended temperature range” components used in critical applications are specified to 80 degrees Celsius.
Use an inexpensive multi-meter with temperature probe and measure the temperature behind the panel at the highest point. If your temperatures start exceeding 50-60 degrees Celsius, internal temperatures of your electronics will be higher and critical levels are reached. It is time to do something about that !
The easiest solution is a few strategic slots on top of the dash to allow natural convection to move the hot air out from behind the panel to be replaced with cooler air from below. In extreme cases or if high power devices are used which create more heat – consider using a small electric fan to assist with air replacement. Small 12V computer fans are easy to get, inexpensive and work well.
Extreme cold temperatures are equally a problem – in much the same way. Consider a small electric, temperature controlled heater behind the panel to assist your valuable electronics

before startup.

## *Ignition systems*

This is often overlooked as a possible source for trouble and we where no different until we found a case. We had an EFIS installation that would work just fine until the aircraft performed a take-off. It would malfunction in strange ways, sometimes just “crashing”.
We looked at all the obvious sources (the above “static discharge” was a prime suspect) but could not find anything until we connected an oscilloscope to the EFIS power supply. When we did – we found a horrible picture with voltage spikes exceeding 80V in both polarities – the moment the engine was running. Increase RPM and it gets worse.
This particular aircraft had a modified VW with a second magneto ignition installed. When this was switched off (using only the original ignition) – all was well. The owner had installed resistorless plugs and caps for his second ignition system. Once resistor plugs where installed the problem went away. This issue was made worse by an incorrect battery ground installation which used the airframe as ground path (that must be avoided at all costs).

## *Grounding*

This is important. Read on:
Grounding is one of the things that is done wrong in most installations. Most of the time, you are lucky and nothing bad happens. There are a few rules that you **MUST** follow:

1) Never use the airframe as convenient ground to supply anything. The airframe must be grounded to the battery negative at one point and one point only. Never connect anything else to the airframe ground. You do **NOT** want currents to flow through the airframe.
2) Separate your grounds and your positive supplies. Heavy duty users (landing lights etc) get their own ground system. Radios, transponders etc also get their own ground system. EFIS systems, GPS receivers etc get their own ground systems too.
   That means you do NOT have a common ground bus rail somewhere in your panel. You have at least three of them and they are not connected to each other. They each get their own connection to the battery negative. The battery negative is your “star” ground point. All the current returns end up here.
3) Radios and high current DC users should have their positive supplies separated from sensitive EFIS systems (you don't want power dips at the EFIS). Radio power supplies can be contaminated by RF during transmission. Keep those separate from the EFIS supply.
4) Do install, at a minimum, a electrolytic capacitor of at least 10.000uF capacity (more is better) as electrical energy reservoir at the EFIS power supply. That means both leads of the capacitor at the EFIS or close to it (it is OK to install the capacitor on your EFIS/instrument supply rail).
   Consider installing a transorb or similar surge protection device over this supply as well. It will ensure that any power surges remain within the limits imposed by DO-160.

Right, now let's have a look at problem areas:

Looking at the complex EFIS, you will find that you will be connecting all sorts of external devices to it – autopilots, servos, radios, engine monitoring systems etc.
Often this means additional grounds between these connections.
This causes “ground loops”. Multiple ground connections to the same point. This is bad. Here is the reason why: Ground loops where you have a physical area inside the loop are very effective antennas. They transmit and they receive. You may ask what ? Easy – your digital electronics, the EFIS in particular – has hundreds, if not thousands of signal sources due to its many systems inside the unit. These produce very small amounts of energy at radio frequency spectrums. These are not normally a problem – unless you provide a nice antenna so they can be radiated. Your VHF radio is a AM radio and very sensitive to this kind of thing. If you find you can hear your EFIS on your radio and it is more than at the normal ambient “hiss” level – you most likely have created a nice antenna accidentally, connected to your EFIS.
Ground loops work as receive antennas as well – you have a powerful signal close by from your VHF radio and your ground loop will absorb some of this signal – possibly causing issues for your EFIS but this is also transmit power lost for your radio.
Then we have ground faults – these can be bad (and expensive).
Here is an example: You have a powerful VHF radio that is connected to your EFIS via a RS232 port so the EFIS can set frequencies. The radio has a ground connection for its power supply. The EFIS also has a ground connection. Yes, we have a big ground loop but let's just disconnect the ground from the radio (the cable “broke”). Everything will still be working right ? The radio will get its ground now from the EFIS. Now you press your PTT and smoke happens. The radio has forced a few amps of current into the EFIS signal ground (on the RS232 port) and its blown up part of your EFIS as it was never designed to handle large currents here.

So what do you do about this ?
Two solutions:

1) In most cases signal grounds are not needed as all devices are powered by the same source (your battery). There is usually not a reason to wire a RS232 ground.
2) If a ground is mandatory – and it is a signal ground (practically no current flow), consider installing a resistor in line (for example 100 ohms). This will effectively “break” the ground loop, still provide a low current connection and nothing bad can happen if you have a ground fault.

If a potential ground loop is unavoidable for whatever reason: You can avoid the ground loop from becoming an antenna quite easily: The antenna needs a physical area to operate – so if you route the ground cables next to each other – there is no area – right ? Simple...

## *Shielding wires*

Sometimes you need to shield wires. Often the shield of a wire is a foil or braided copper. Never use the shield to carry current (like the ground current). Connect your shield on one side only. That is the easiest way to ensure that your shield is good. If you need to carry ground current as well – make sure you have a spare inner core for this. This means you will shield the ground as well. Not a bad idea (trust me).

## *Good ideas*

We know EFIS power supplies are sensitive and to some extent this applies to other electronics as well.
It makes sense to pay some attention to this. One of the best investments you can do to protect your expensive EFIS is to fit a galvanically isolated power supply regulator. This device takes power from your battery and converts it into a magnetic field – that field is then converted back into electrical power for your EFIS.
This device provides complete isolation. That is very good. It also provides clean, regulated DC to your EFIS no matter what happens on its input. A good device will accept input voltages in the range of as little as 9V up to as much as 36V and provide a very good quality supply to your EFIS and other sensitive electronics.

## *Bad ideas*

We often find very neatly done wiring harnesses behind the panels. Bundles of cables are neatly tied together and routed to their various destinations.
Looks good – can be a very bad thing.

From an electrical point of view a “rats nest” of cables is better (but does not look very good). The reason is that electrical currents create small magnetic fields around its cable. These field then create electrical currents in cables that are close by. Long cable runs where the cables run next to each other make that worse. For high frequencies, we have a further issue in that we also have “capacitive coupling” - any two wires form plates of a capacitor (and that “conducts” high frequency signals).

This means you have to pay a bit of attention to what you are bundling together. Simple conductors of DC (power to various users) is not a problem. But when we start throwing in data and signal cables – things get interesting. Keep those separate from each other as much as you can.

RF cables are another issue – never route these inside wire bundles with other conductors – that is simply asking for trouble. Keep your radio and transponder RF coax cables away from everything else. There is black magic happening in these cables and it does bad things.