# CMF™:
## Its purpose and
## The Technology
## Behind it

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# What is a Sine Wave Filter?

- A Sine Wave Filter (SWF) is a vital component of a Filtered Pulse Width Modulated Adjustable Speed Drive (FPWM ASD).

- The SWF is the 'F' in the FPWM ASD and its purpose is to recapture the intended sine wave from the pulsed output.
  - SWFs are not all equal in their success at recapturing the intended sine wave.
  - SWFs almost exclusively utilize a series inductance and parallel (L-L) capacitance.
    - The purpose of the series inductance is to impede series flow of high frequency content,
    - The purpose of the parallel (L-L) capacitance is to allow parallel flow of high frequency content from line to line.

# What are the Limitations of a SWF?

- The Series Inductance:
  - In a theoretically ideal inductor, the impedance presented increases with the frequency.
    - No theoretically ideal inductor can exist due to the unintended capacitance that exists between the turns of conductor.
      - This capacitance has a negligible effect on the circuit at the fundamental frequency but is significant at higher frequencies.
      - Every real inductor has a self resonant frequency.
        - Below this frequency, it behaves as an inductor.
        - At this frequency, it behaves as a resistor.
        - Above this frequency, it behaves as a capacitor.
  - Inductors don't stop high frequency, they impede the flow of high frequency.

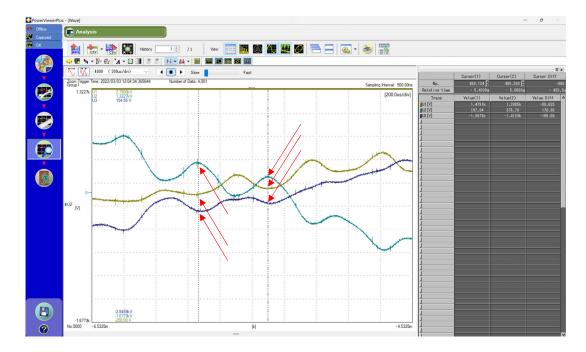# What are the Limitations of a SWF?

- The Parallel Capacitance (L-L):
  - The parallel capacitors allow high frequency to flow from one line to another while impeding flow of lower frequencies such as the fundamental.
    - Flow occurs from high potential to low potential, so for high frequency flow to occur, a high on one line requires corresponding lows on the other lines.
      - This high frequency noise with corresponding highs and lows referenced phase to phase is called Differential Mode Noise.
  - There can be a significant amount of high frequency, differential mode noise passing through these capacitors.
    - The current passing through results in a buildup of heat which, when combined with elevated ambient temperatures, causes the capacitors to fail.
      - When the SWF capacitors fail, there is no longer a  phase to phase path for high frequency which causes the series inductance to heat, the step-up transformer to heat, and the remaining high frequency differential mode noise to search the downhole circuit for a path phase to phase.

# What are the Limitations of a SWF?

- The Parallel Capacitance (L-L):
  - The output of a PWM ASD is a complex waveform with both differential mode (L-L) noise and common mode (L-N) noise.
  - The phase to phase arrangement of the Parallel capacitors does not allow for flow of common mode noise as all three phases go high and low together when referenced to ground.
    - Common mode noise will eventually create a path to ground resulting in damage to the downhole ESP circuit.
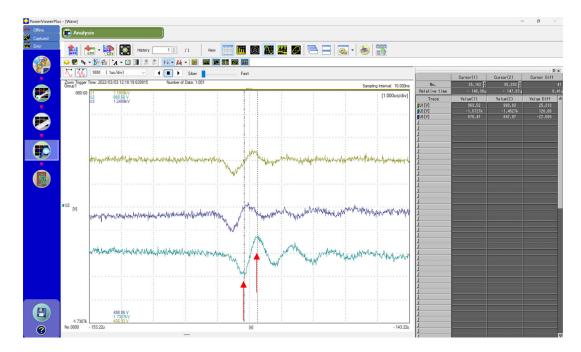
# Differential Mode Noise:
# Example from a FPWM ASD with 2.3KHz carrier frequency.

- The waveforms have been arranged to allow better observation of the corresponding highs and lows. (200μs/div, 500ns sampling interval).

- Differential Mode Noise causes phase to phase failures.

# Common Mode Noise:
# Example from a FPWM ASD.

- The waveforms have been arranged to allow better observation of all three phases going high and low referenced to ground. (1µs/div, 10ns sampling interval).

- Common Mode Noise causes phase to ground failures.

# How does the CMF™ work?

- The CMF™ is a passive, wye-connected device wired in parallel with the downhole ESP circuit.
- The CMF™ consists of a resistor bank and capacitor, for each phase, connected to ground.
  - The resistors are of a proprietary design and material to maintains its impedance independent of the frequencies presented.
  - The capacitors are reactive and thus present high impedance to the fundamental frequency while presenting low impedance to high frequencies.
  - The effect is the CMF™ provides a preferential path to ground for high frequency common mode noise.

# How does the CMF™ work?

- The CMF™ capacitor arrangement also provides for a path for high frequency, differential mode noise (half the capacitance as phase to ground).
  - This results in excessive current through the CMF™ when failure occurs in the SWF installed in the FPWM ASD.
    - The excessive current causes a fuse to open in the CMF™ which triggers an alarm output to an I/O in the ASD.
      - This is the sole failure mode of the CMF™ and is corrected by repairing the SWF and replacing the fuse in the CMF™.
    - This is currently the fastest way to be notified of SWF failure and provides this notification before damage has begun to occur to the downhole ESP circuit.

# Layout of a site using CMF™.

# Key Points

- The SWF in the ASD filters only differential mode noise.
- The CMF™ is designed to filter common mode noise and requires a functional SWF for proper operation.
  - The CMF™ augments the SWF by filtering what the SWF allows to pass.
- The CMF™ can be modified for use with Six-Step ASDs which do not have a SWF.
- In FPWM applications, the CMF™ also acts as an early warning system notifying of SWF component failure prior to damage occurring to the downhole circuit.
  - Upon notification, simply repair/replace the SWF and replace the fuses in the CMF™.