

MOV Backseat Relay Model 201602

Technical Bulletin – RMS vs. Summation Sampling Describing firmware version 3.X upgrade from 2.X

MOV Backseat Relay firmware versions 2.X sampled 3 phase data and added the three instantaneous readings together with scaling and filtering to get a total current reading. This method worked well in lab testing and in at least one in-plant application. While developing a DC version of the relay, the sampling method was reviewed and it was determined that using RMS calculations gives better results by eliminating sine wave ripple from overall signal noise.

Summation method (Version 2.X)

Three incoming phases are sampled by 10 bit A/D converters at a rate of 3600 samples per second, or 60 samples per cycle of 60 Hz line frequency. The zero offset is subtracted, the absolute value of each phase reading is determined and a calibration constant is applied. The three phases are then added together to give an instantaneous current reading. A digital filter is applied to smooth ripple and reduce the response to noise. The filter is a declining average with older readings fading from the result. The filter has the form:

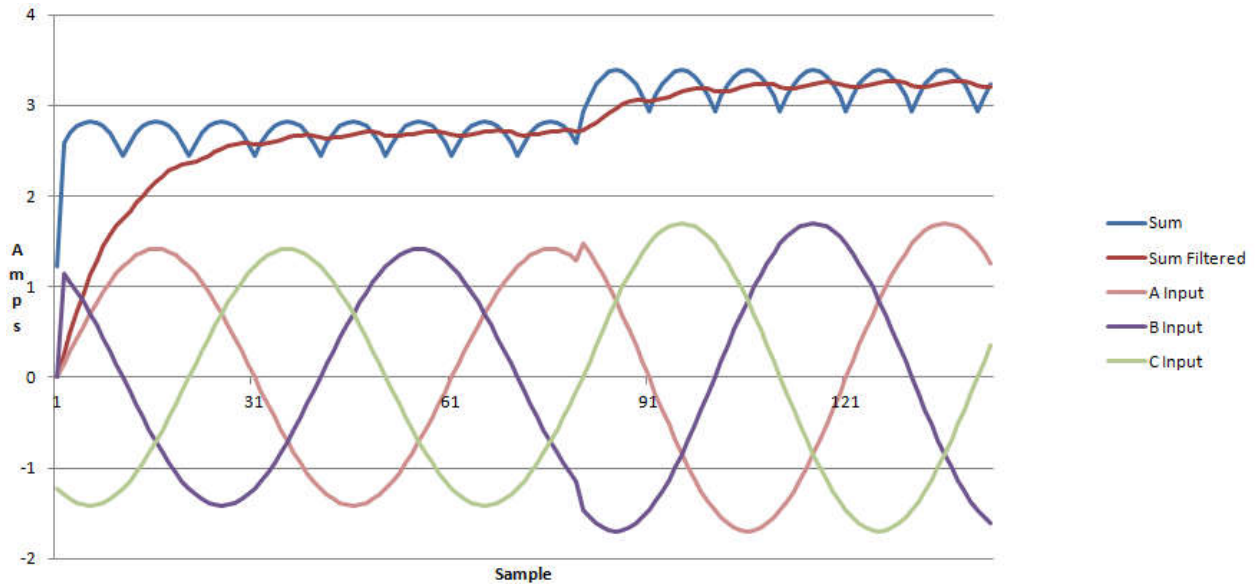
$$A_f = A_f - (A_f - A_n) / f$$

Where

- A_f = filtered current
- A_n = new current reading
- f = filter constant (a value of 1 means no filtering)

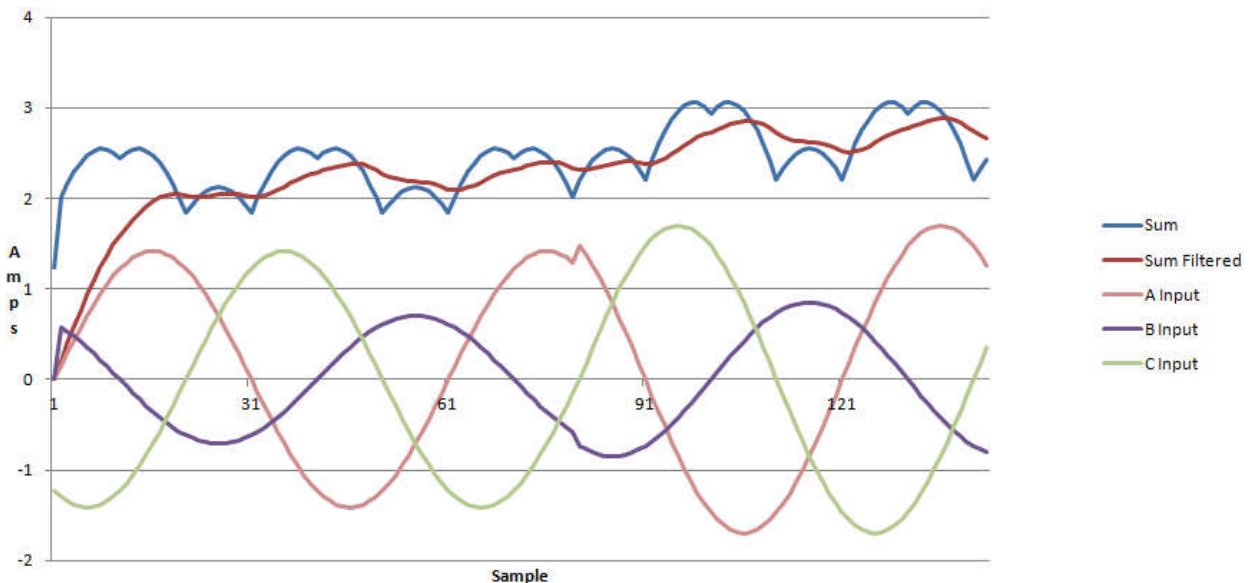
The default filter value is 10, which was determined during prototype lab testing.

The following chart is an Excel simulation of the response to a balanced 3 phase signal. It represents an initial step from 0 to 1 Amp RMS on each phase followed by a step increase to 1.2 Amps. The Sum trace is the sum of the absolute values of the phases, while the Sum Filtered trace includes a filter constant of 10.



The summation gives a very fast response with no filtering, but to make it useable the filter is added. This slows the response but reduces the chance of a false trip. Some ripple exists even after filtering. A larger filter constant will reduce the ripple and slow the response further. The relay algorithm establishes a trip setpoint as a percentage above the minimum current during the operate phase of the run. That minimum current will occur at the bottom of a ripple, so the trip setpoint must be set high enough to allow for ripple.

The above trace is with three probes having the same sensitivity and all three phases having equal amplitude. Now consider if Phase B amplitude is half the others, possibly due to a defective probe.



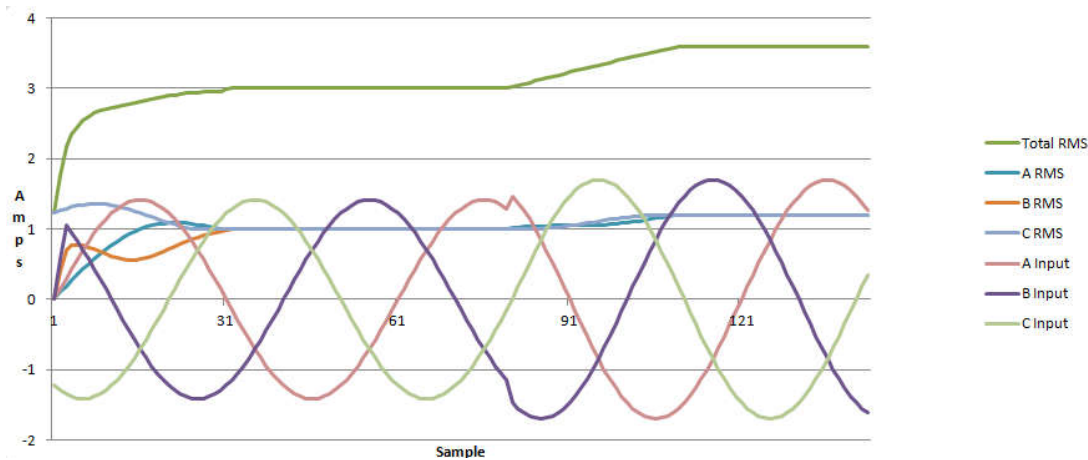
This may be an extreme example, but it illustrates the effect of probe imbalance. Versions 2.X have a lost phase detection test that will trip if any phase is less than 20% of the sum of all phases over ½ cycle. This example would not trip on lost phase, but would probably give an operating current trip before reaching the backseat. Versions 2.3 and 2.4 have a phase compensation option (disabled by default) that will attempt to balance the phases during the delay portion of the run, but the user would have to suspect a problem and enable the option.

RMS Method (Version 3.X)

Firmware version 3.X replaces the summation with a moving RMS calculation. Root Mean Square (RMS) is the square root of the sum of the squares of n samples. In version 3.1, n = 30, which is the number of samples in ½ cycle (8.33 ms). The inputs are sampled and zero corrected as before. The RMS calculation is applied to the most recent 30 samples. This gives an RMS value for each phase.

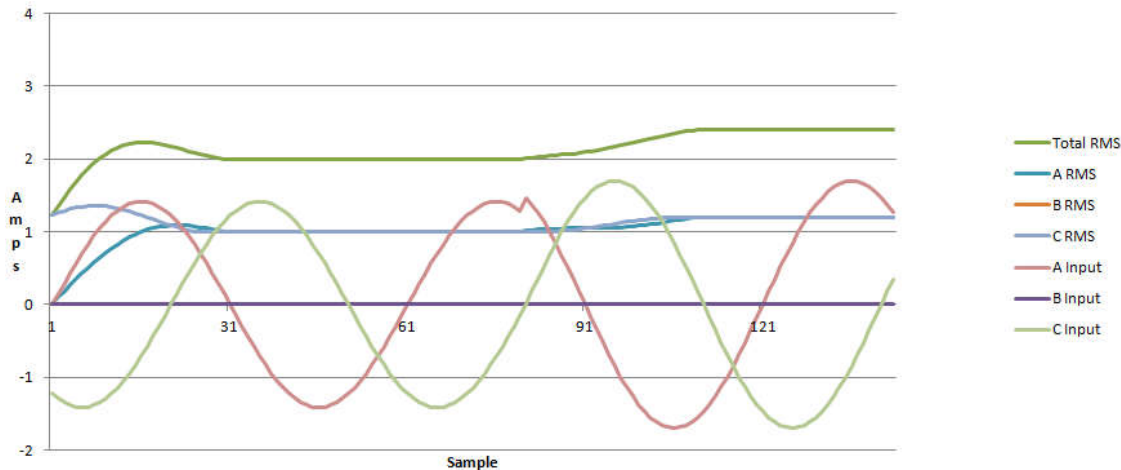
$$\text{RMS} = \sqrt{\frac{1}{30} \sum_{k=1}^{30} x^2}$$

The three phases are added together and scaled to give the total current. With no noise filtering applied (f=1), here is the result for a 20% step with balanced phases.



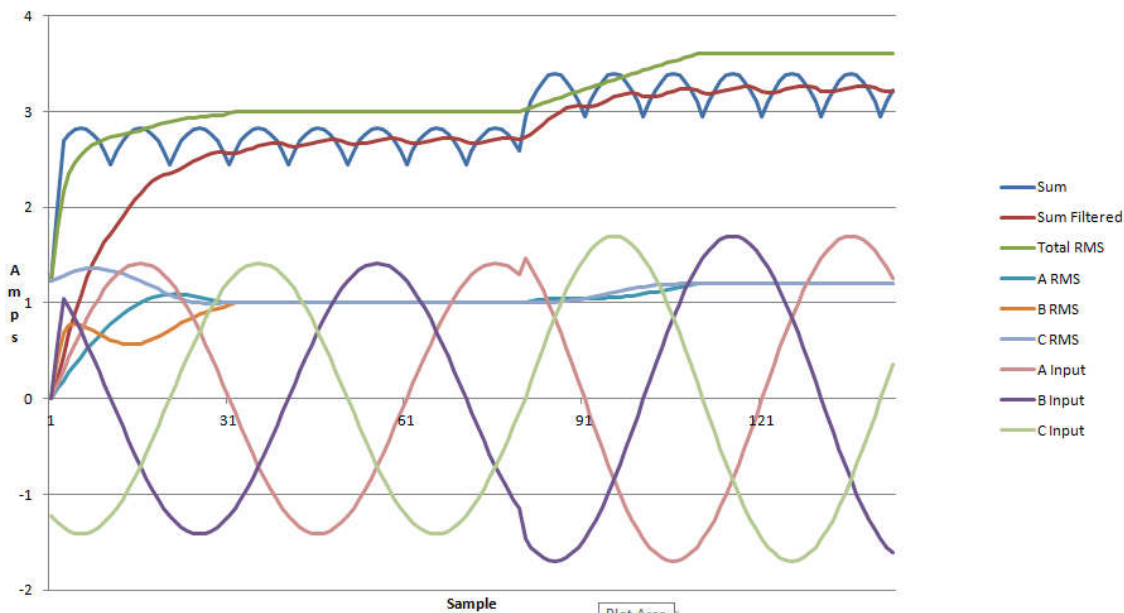
The RMS calculation shows no ripple. Within ½ cycle, the current reading converges to the actual current input. The significance of this is that loss of phase or an imbalance of phase inputs will change the total RMS reading but will not introduce ripple as with the summation method.

Since the operating current trip setpoint is relative, this means that the trip operation is independent of probe condition and the possibility of a premature trip is diminished. You can even run a backseat using a single probe. The displayed and logged current values will display proportionally lower, but the trip function will remain unchanged. In the following example, the 3 phase 3 amp signal comes through as Total RMS of 2 amps with one phase missing, but the relative current change trip function remains unchanged.



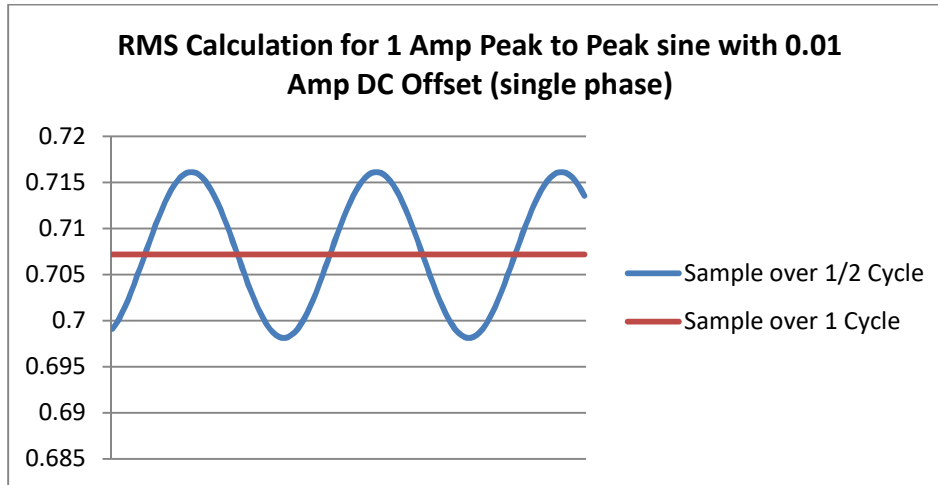
Version 3.X eliminates the phase balance option because it is no longer needed. Lost phase detection is also deleted. The sample filter is retained, renamed as noise filter, and has a default value of 1. The filter value can be increased in case noise is a problem that needs additional filtering.

Here is a combined chart of the summation and RMS calculations for comparison:



Full Cycle RMS

Sampling over ½ cycle works fine as long as the waveform is balanced positive and negative. However, if there is a DC offset, possibly due to calibration variables, a ripple will appear. The solution is to calculate RMS over a full cycle (n = 60). In this case, the offset will cancel out.



This could give a slower response (up to 8.3 ms) to current changes. The reduced ripple (should there be any effect) will increase the margin between signal and trip setpoint, also increasing the time until the trip setpoint is reached.

Compare Trip Times

The RMS calculation gives more filtering compared to the 2.X sample filter set to 10. This results in longer time to trip. To quantify the difference, code was written to simulate the trip time for various settings. Floating point variables were used in the code, so the effects of 10 bit resolution in the backseat relay are not considered. Here are the equivalents. Note that sampling ½ vs. 1 cycle makes only a slight difference in trip time assuming no DC offset.

Summation (2.X)	RMS (3.X) Filter = 1
Setpoint = 110%, Filter = 10	Setpoint = 107.6%, Samples = 60
Setpoint = 110%, Filter = 50	Setpoint = 110%, Samples = 60
Setpoint = 110%, Filter = 10	Setpoint = 107.8%, Samples = 30
Setpoint = 110%, Filter = 44	Setpoint = 110%, Samples = 30

Summary, Version 3.0 from 2.4

- RMS calculation over ½ cycle eliminates phase ripple from any overall noise signal.
- Relay can operate on one, two, or three phases of a 3 phase AC motor
- Phase balance option is deleted since it is irrelevant
- Loss of phase detection is deleted (ver 3.1 will trip on all probes failed)
- Noise filter (previously called sample filter) default is set to 1
- Support is added for DC valves (hardware change is required)

Summary, Version 3.1.1

- RMS is calculated over 1 cycle

The 2.4.1 and 3.1.2 updates are not applicable to this discussion. Version 4.0 used in the new AC/DC relay also calculates RMS over 1 cycle. A/D conversion is 12 bits to give better resolution.