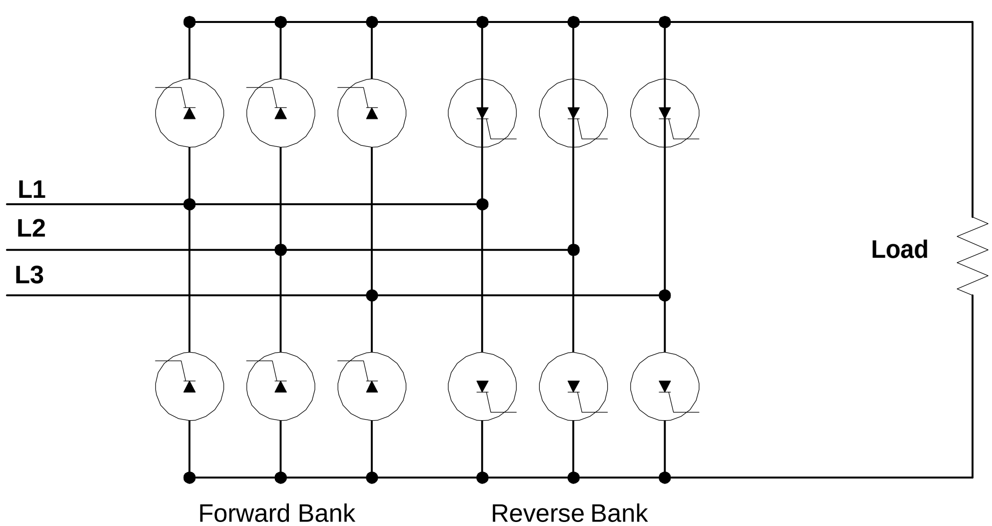
# Waveforms from a Six Pulse DC Drive using Phase Angle Fired SCRs

The question arises as to what the applied waveform looks like and how one can monitor the current and voltage applied to the DC motor.

This type of controller is used to vary the effective voltage applied to the DC motor. It does so by rectifying AC voltage supplied from a three-phase source. SCRs (Silicon Controlled Rectifiers) are gated. When a voltage is applied to the gate, the rectifier will conduct until the next zero crossing of the voltage. The gating voltage may be applied at any point following the zero crossing between zero$^+$ degrees and 180$^-$ degrees, and between 180$^+$ degrees and 360$^-$ degrees. The smaller the angle, the longer the rectifier conducts. (I used zero$^+$ to indicate just following the zero crossing and 180$^-$ to indicate just before the zero crossing.)

The graphs on the following pages illustrate what happens as the firing angle is increased from zero degrees (full conduction) through 180 degrees (no conduction). The graphs are paired. The first shows a single phase rectified and the second shows the sum of all three phases.

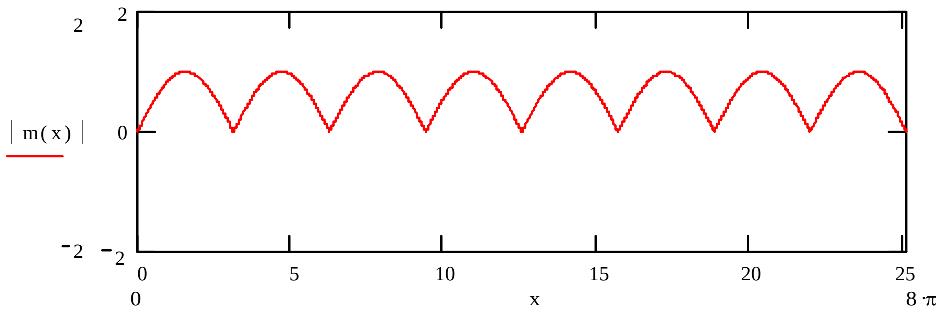



Six Pulse Reversing Bridge.

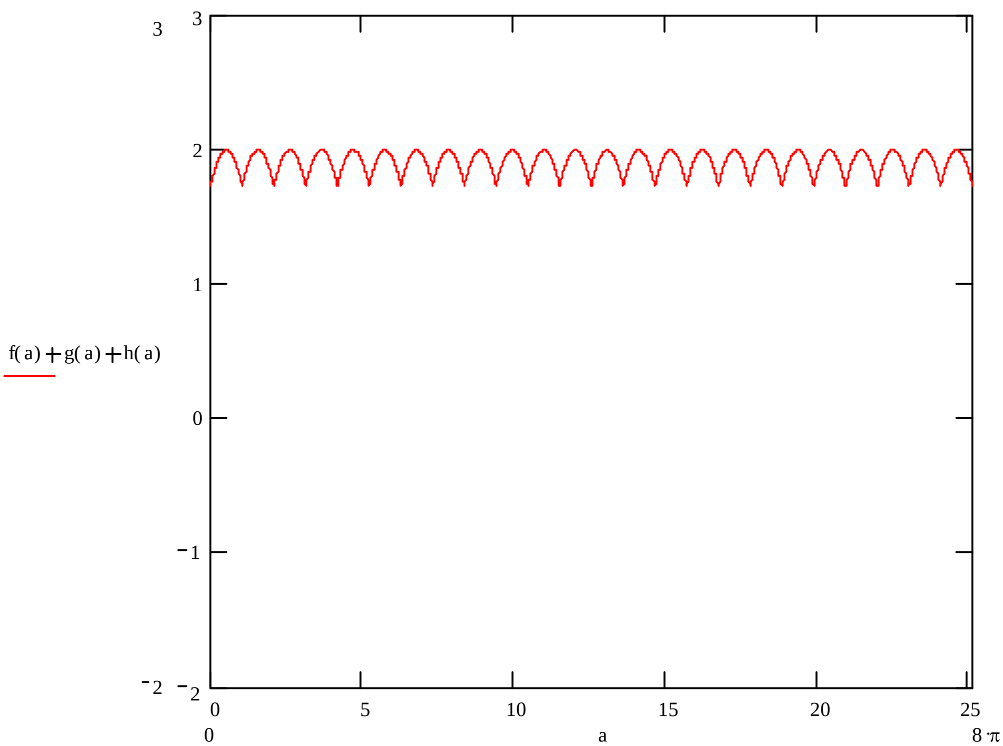
The figure above illustrates a six pulse reversing SCR phase angle controller. When the gates on the forward bank are activated, the current flow through the load is clockwise. When the gates on the reverse bank are activated, the current flow through the load is counter-clockwise. The firing angle controls the effective voltage thus the current through the load.

**Please go to page 14 for monitoring solutions.**

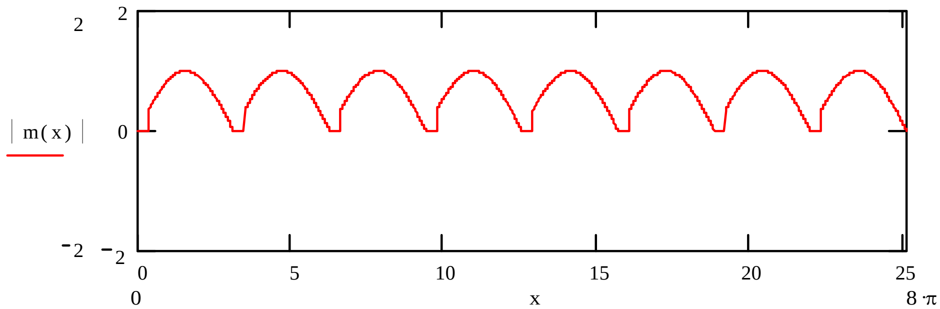
**Firing angle 0 degrees.**
**Single phase.**



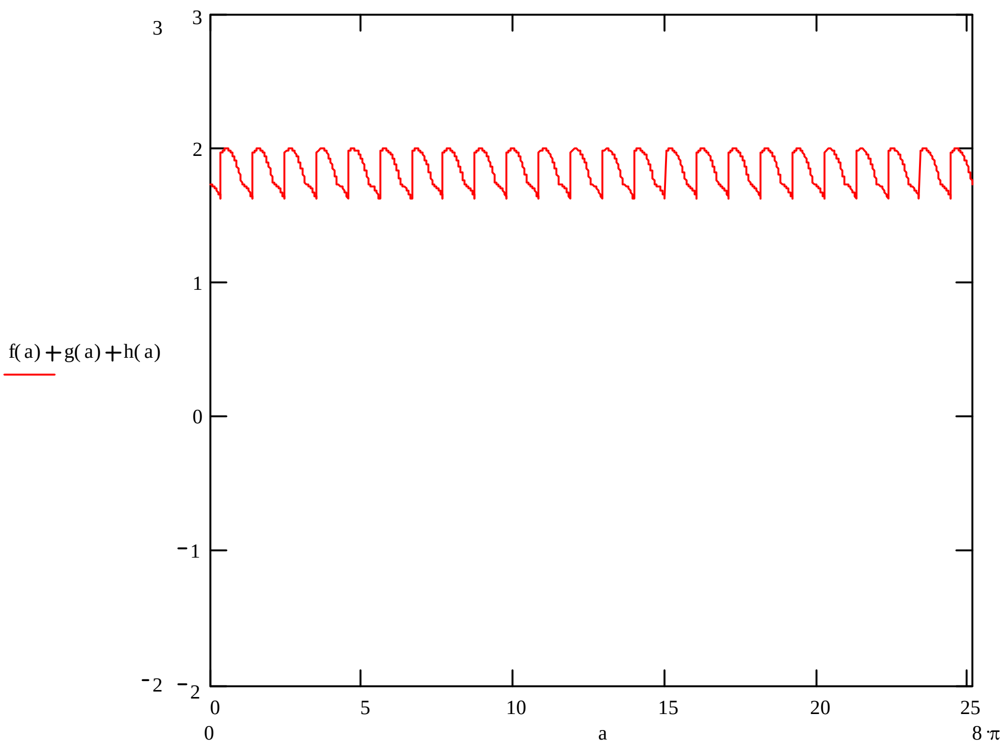

**All three phases.**



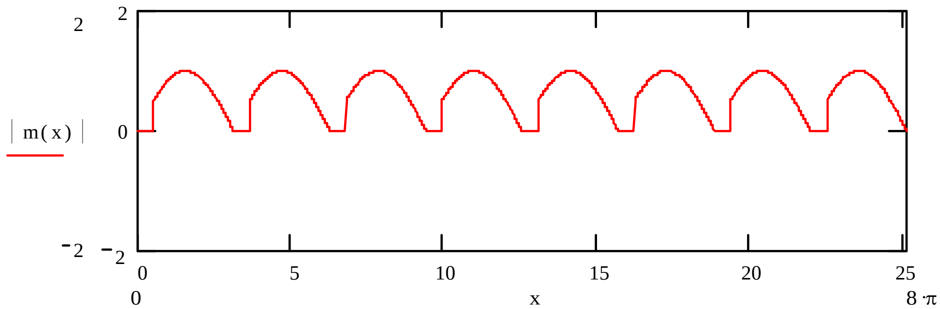
**Firing angle 20 degrees.**



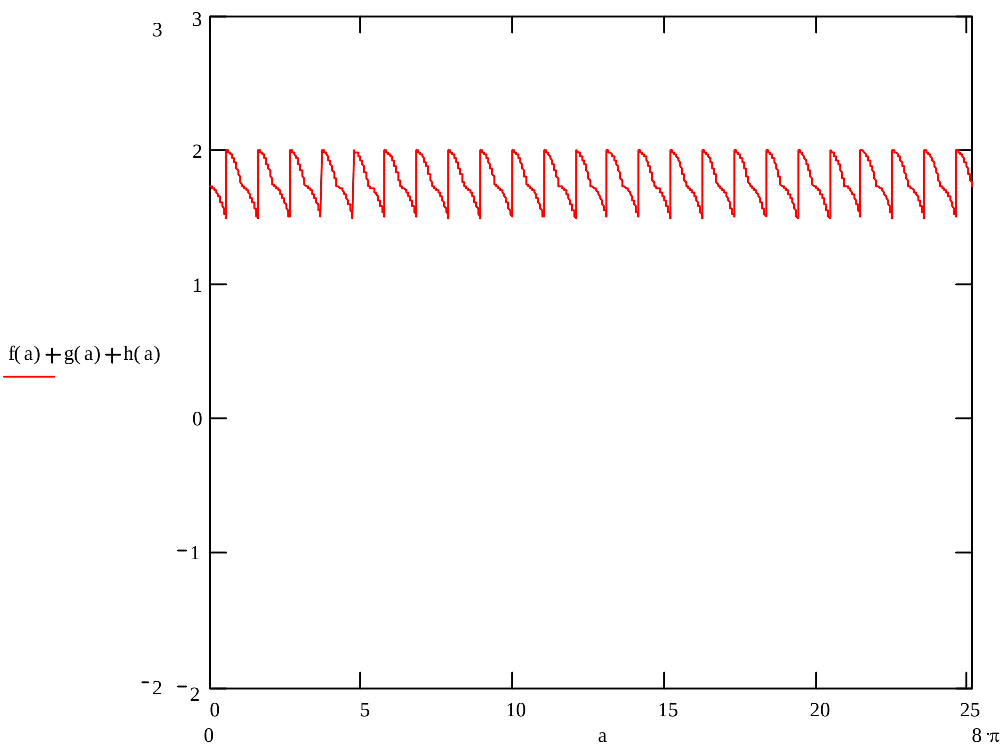

**Top single phase**
**Bottom all 3 phases**



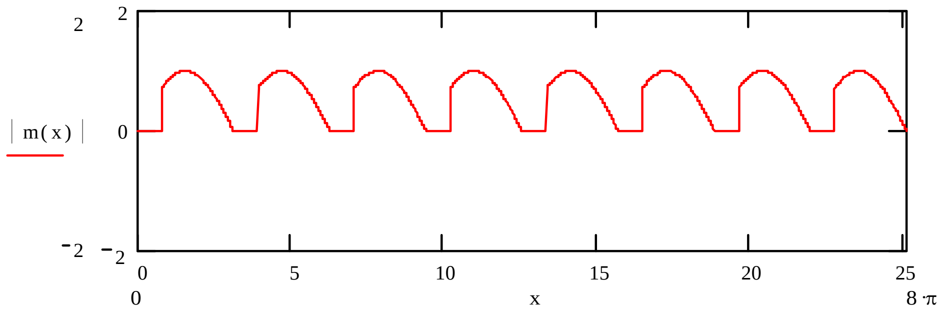
**30 degrees.**



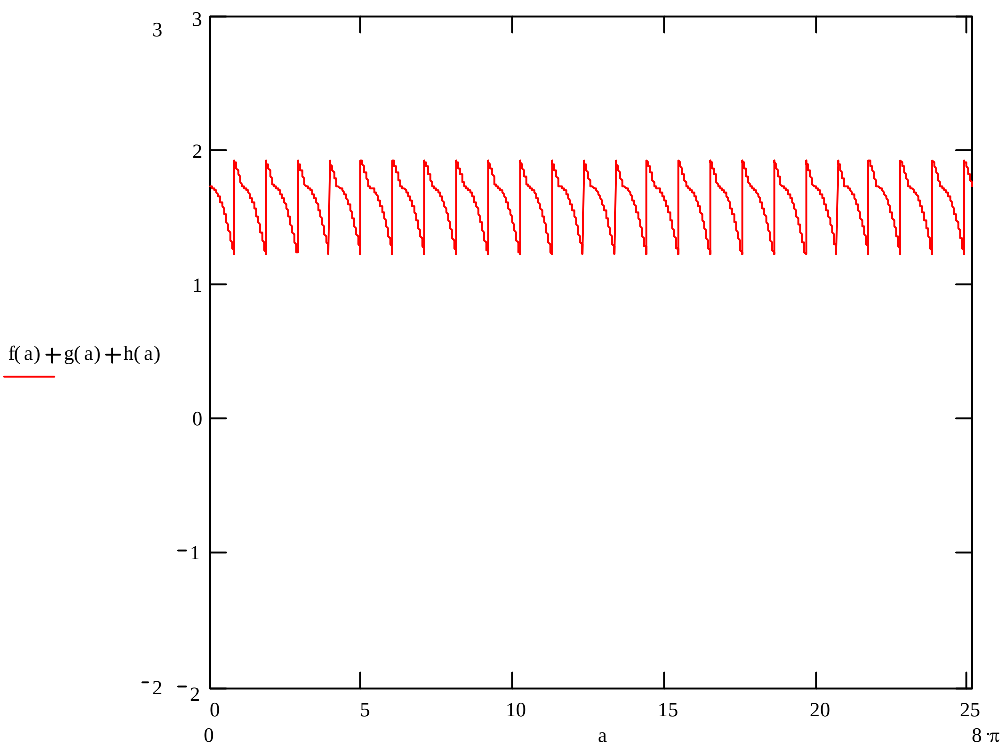

**Top single phase**
**Bottom all 3 phases**



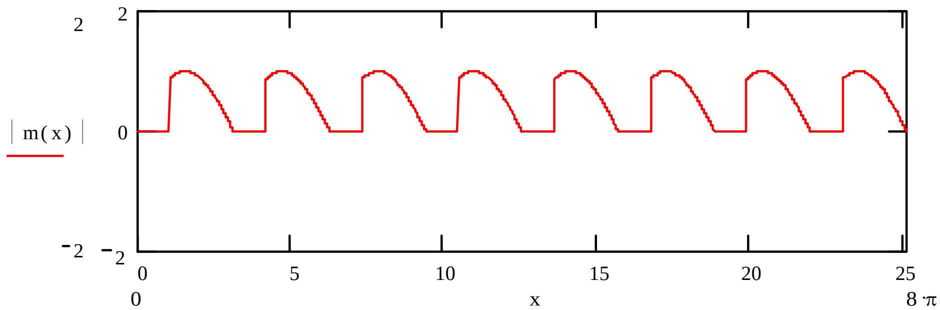
**45 degrees**



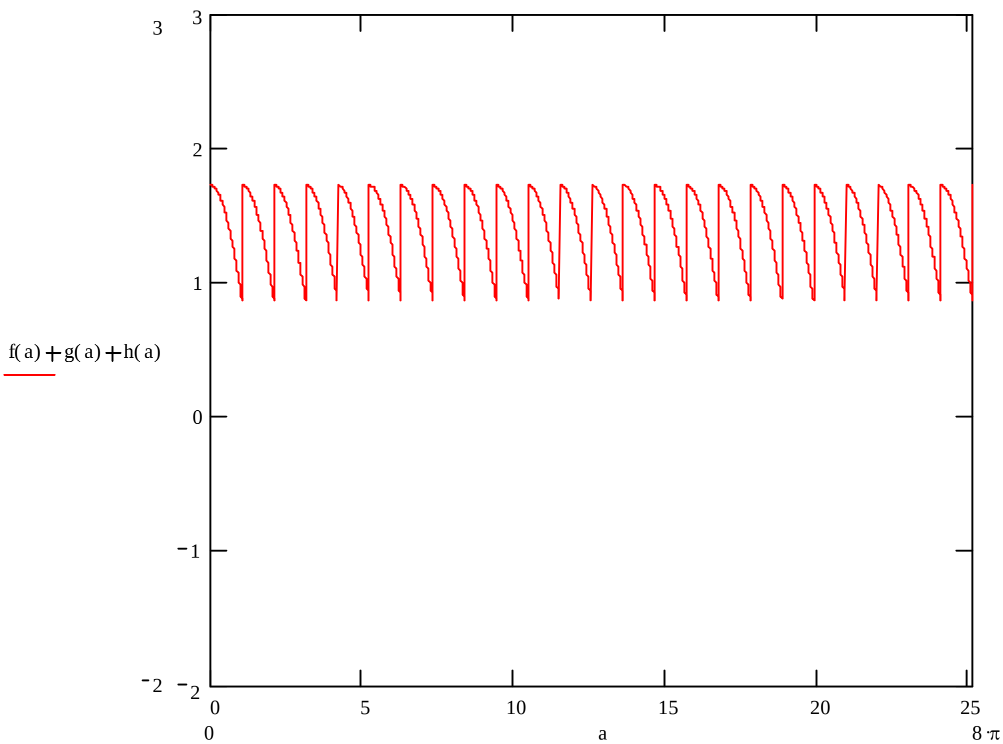

**Top single phase**
**Bottom all 3 phases**



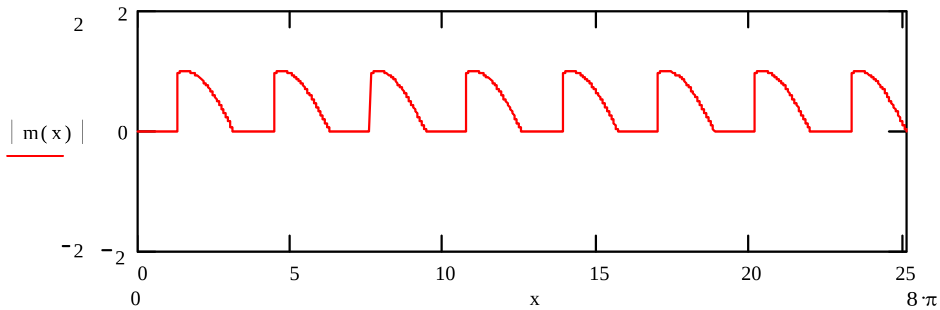
**60 degrees.**



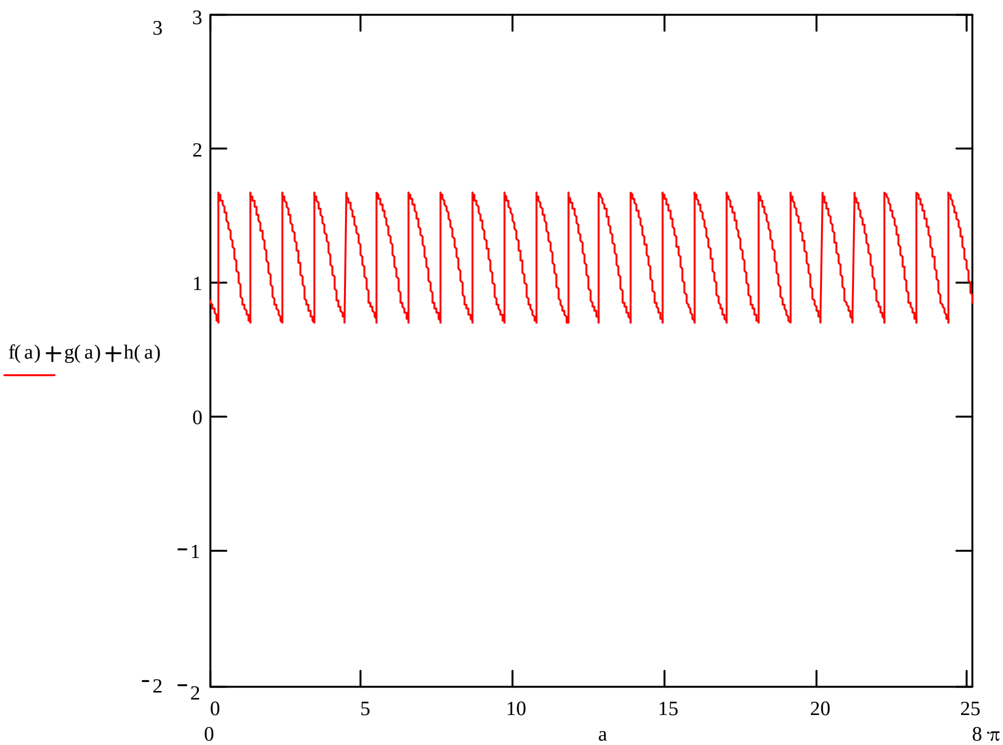

**Top single phase**
**Bottom all 3 phases**



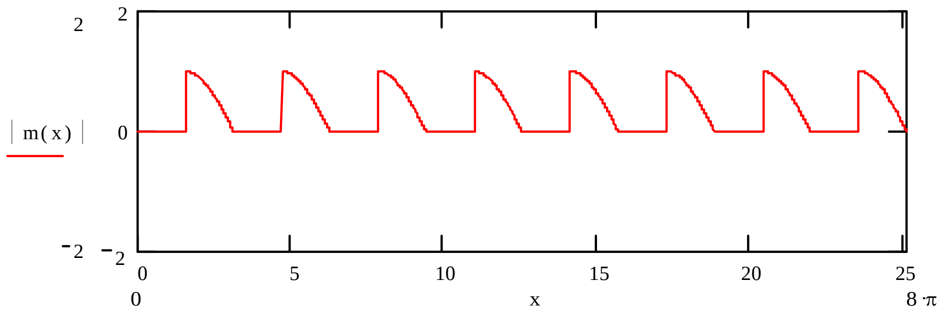
**75 degrees.**



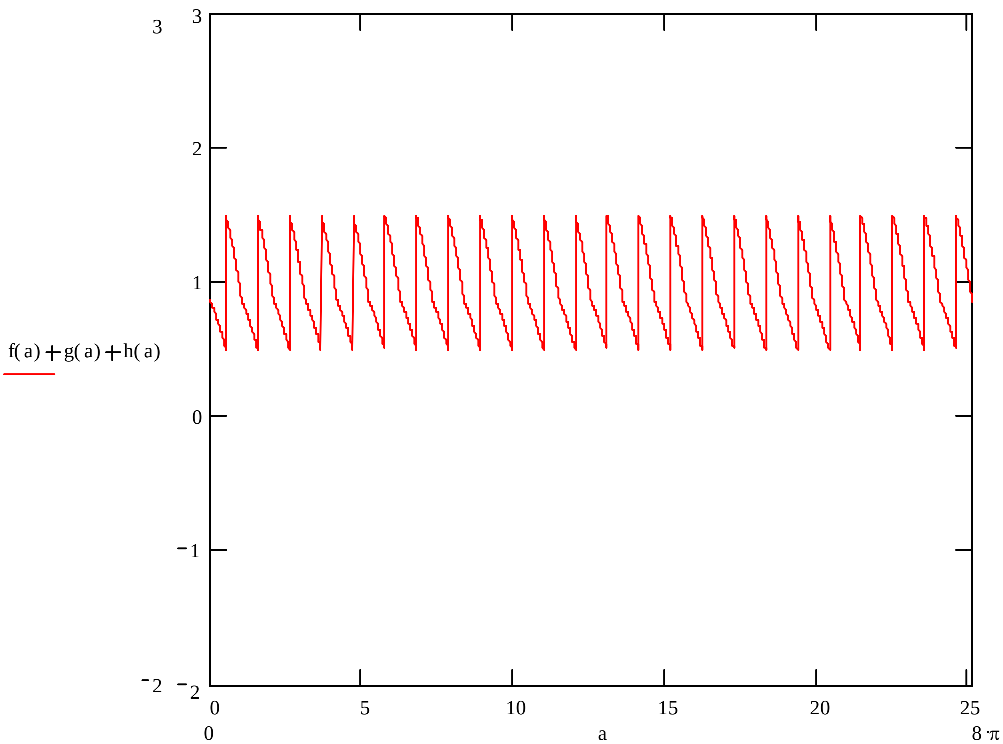

**Top single phase**
**Bottom all 3 phases**



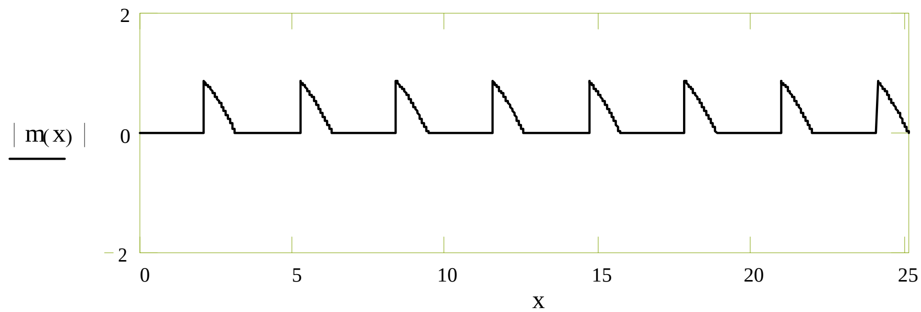
**90 degrees.**



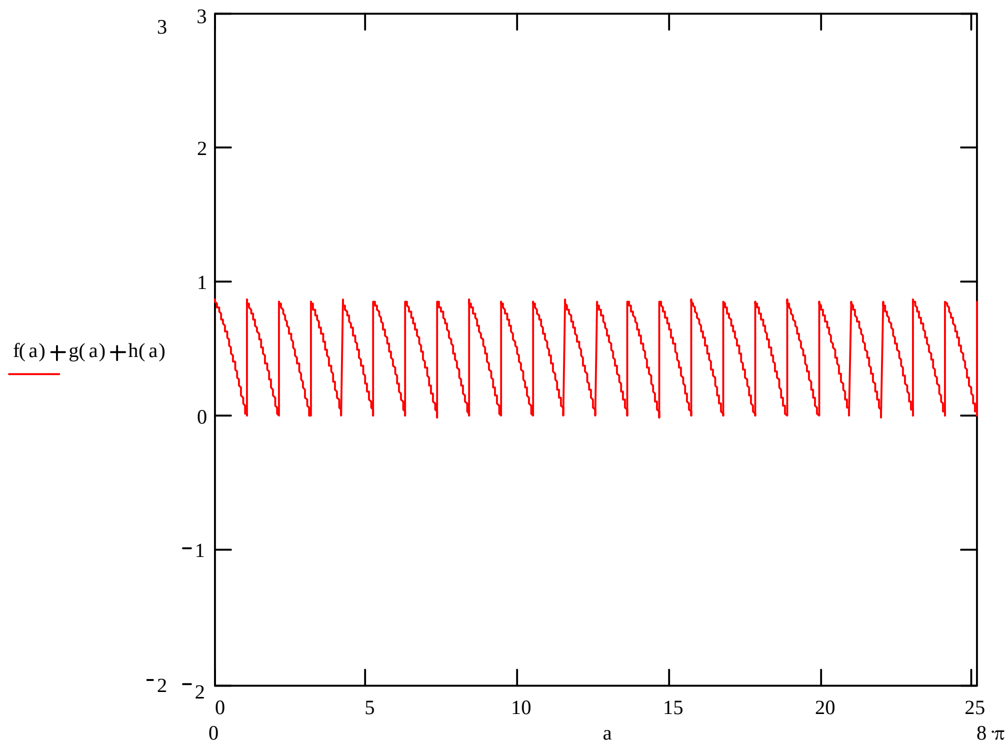

**Top single phase**
**Bottom all 3 phases**



**120 degrees.**

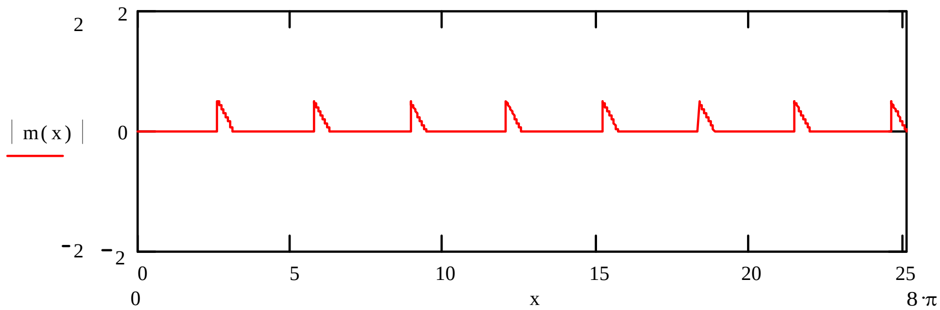



**Top single phase**
**Bottom all 3 phases**

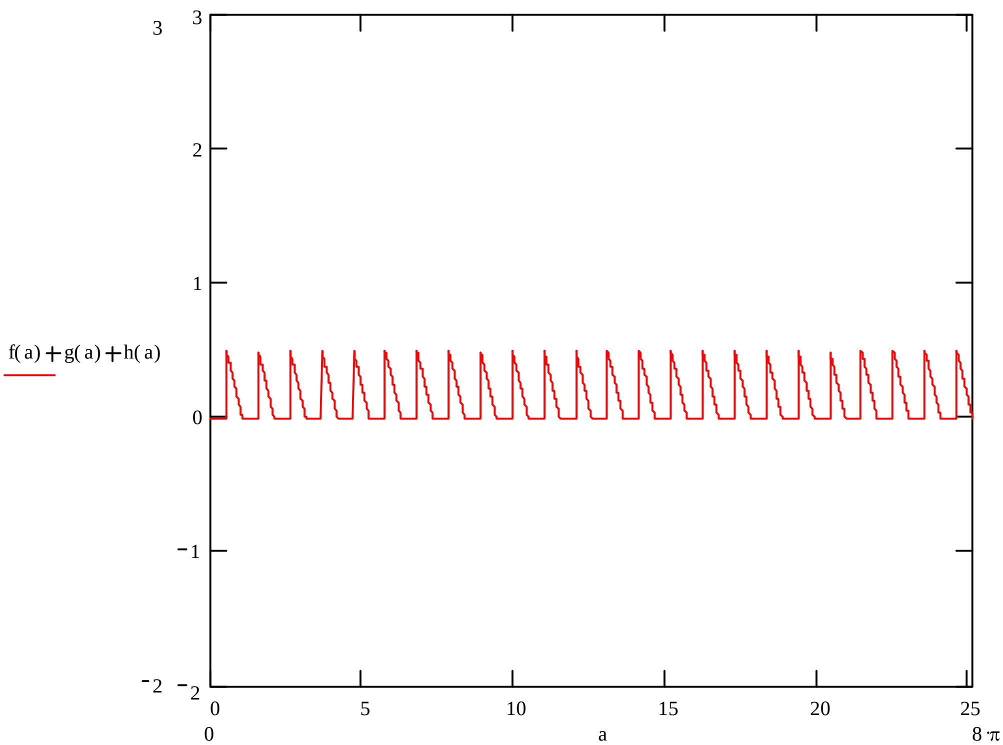



Notice that at 120 degrees, the base of the waveform (the sum of the three rectified phases) is at zero.

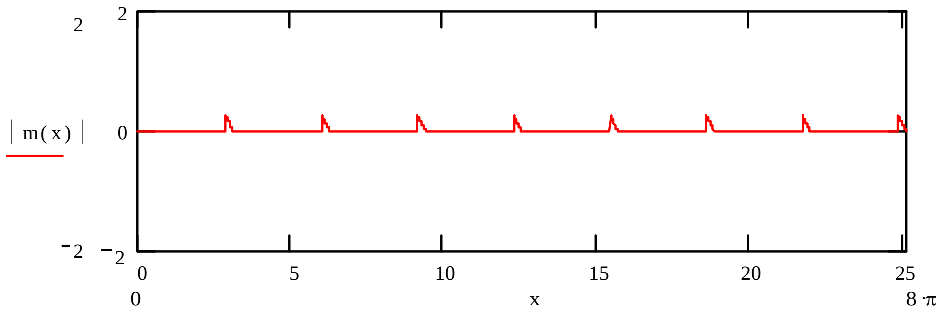
**150 degrees.**



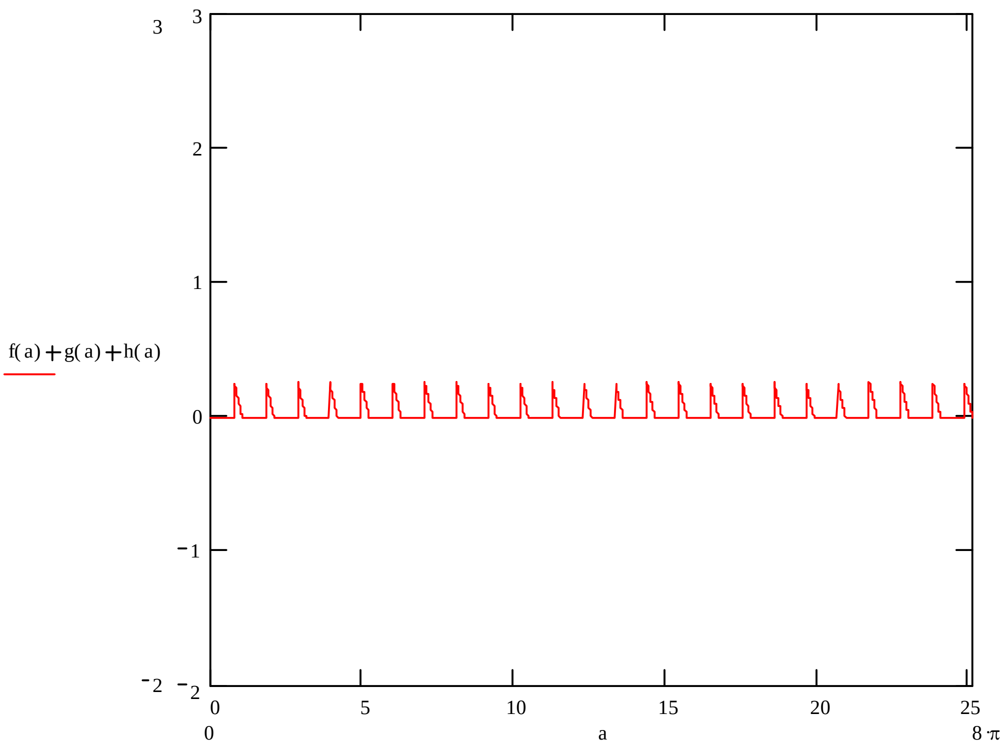

**Top single phase**
**Bottom all 3 phases**



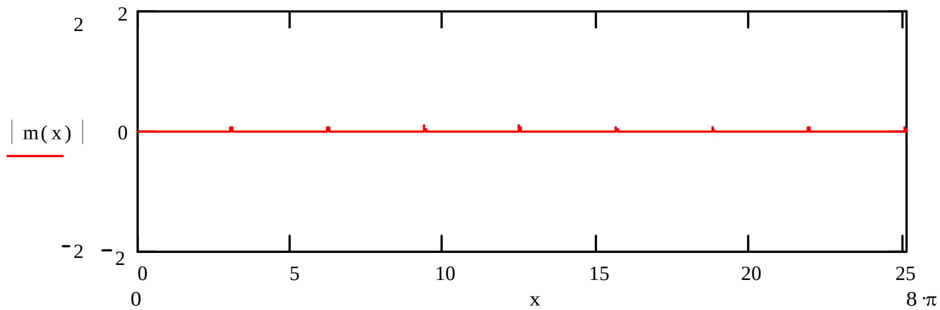
**165 degrees.**



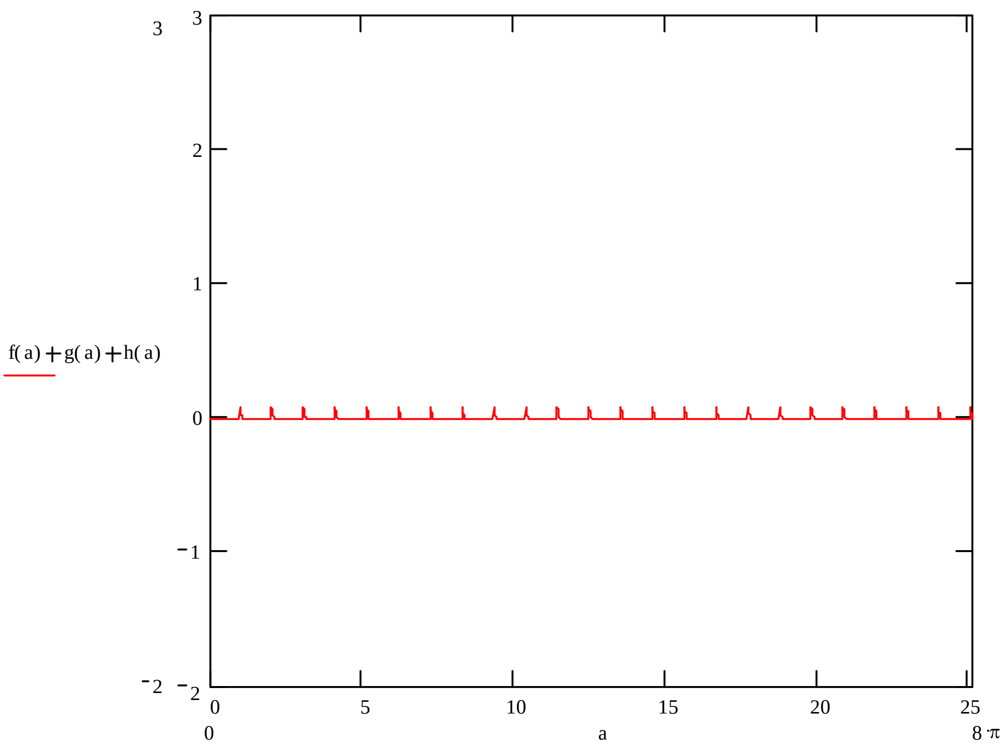

**Top single phase**
**Bottom all 3 phases**



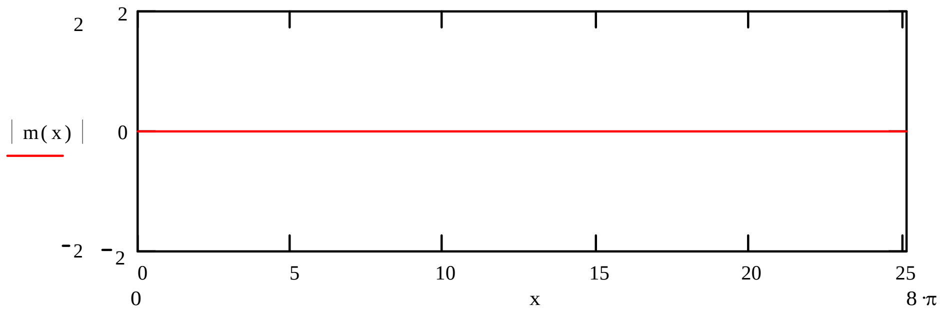
**175 degrees.**



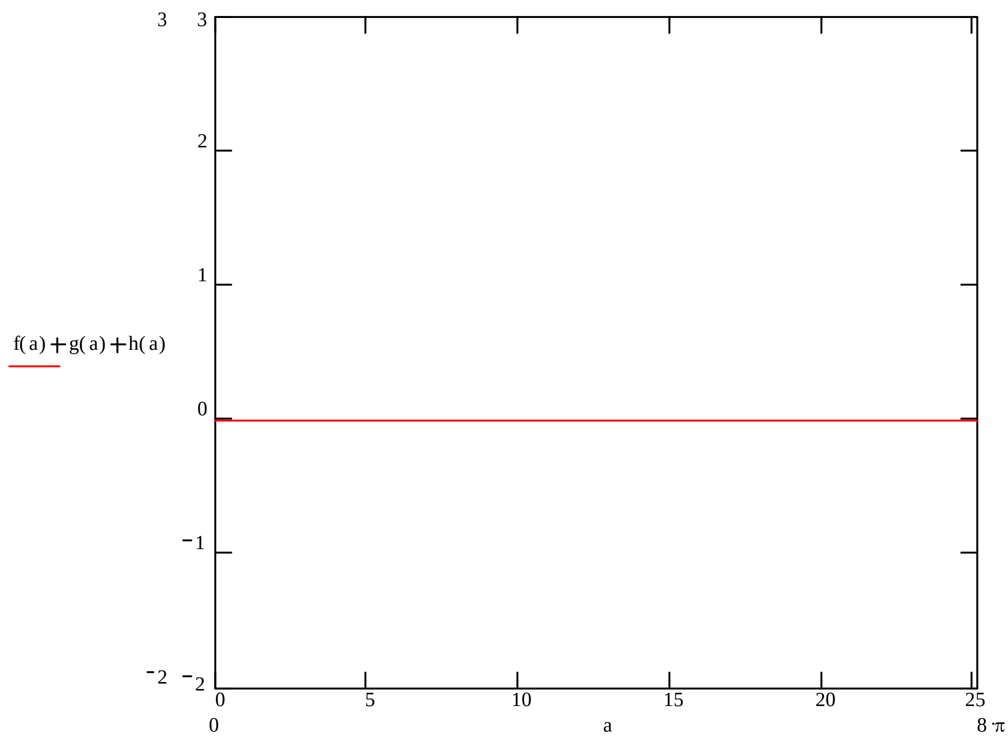

**Top single phase**
**Bottom all 3 phases**



**180 degrees.**




**Top single phase**
**Bottom all 3 phases**




After 180 degrees the reverse bank will begin firing and the pattern will reverse in polarity.

## How to Monitor

### Current

Ohio Semitronics, Inc. recommends using the CTL series of current transducers along with the appropriate direct measuring signal conditioner. Add the suffix "Y25" to the model number of the signal conditioner. This "Y25" option provides filtering of the pulses averaging the value. This combination will provide an accurate output that represents the DC average of the measured DC current. The output response is 100 milliseconds to 90%.

Examples:

1) A DC motor has a full load rated current of 1000 amperes and is connected using a single cable.

Use the CTL-202/1000 current transducer with the CTA201Y25 signal conditioner. This combination will provide an output of 0 to +10 volts DC representing 0 to +1000 amperes or 0 to -10 volts DC representing 0 to -1000 amperes.

2) A DC motor has a full load current of 2500 amperes and is connected using 4 inch bus bar.

Use the CTL-502H/2500 current transducer with the CTA201HY25 signal conditioner. This combination will provide an output of 0 to +10 volts DC representing 0 to +2500 amperes DC or 0 to -10 volts DC representing 0 to -2500 amperes DC.

### Voltage

Use the VT7 series of voltage transducers adding the suffix "Y22." This "Y22" option provides filtering of the pulses averaging the value. A VT7 series transducer with this option will provide and accurate output that represents the DC average of the measured DC voltage. The output response is 100 milliseconds to 90%.

### Pricing

The Y25 filter option for the CTA signal conditioners and the Y22 filter option for the VT7 voltage transducers adds $65.00 to the base price of the transducer. As models with these options are not in our finished goods stock, please allow two weeks for shipment from our factory. Please do check with our factory if you have any questions and to confirm prices. (Prices given are effective Dec. 2004.)

### Power

The PC8 series of watt transducers is designed specifically for measuring DC power. This series will accurately measure power delivered to a load over a frequency range of DC through 400 Hertz. The output response of the PC8 watt transducers is 250 milliseconds. It is ideal for measuring DC power delivered from a six-pulse phase angle fired SCR.

Examples:

1) A 500-volt DC motor has a full load rated current of 1000 amperes and is connected using a single cable. Use a PC8-006-06D watt transducer. This comes supplied with a 1000 ampere Hall effect current transducer and accepts the 500 volts direct. 0 to 10 volts DC will represent 0 to 500,000 watts.

2) A 500-volt DC motor has a full load current of 2500 amperes and is connected using 4-inch bus bar. Our catalog does not list a transducer for this application. However, OSI is very flexible. This will be a PC8-006-07DY60 that comes equipped with a Hall effect current transducer with a 4.5 by 1.25 inch opening for the 4-inch bus bar. The PC5-006-07DY60 will provide an output of 0 to 10 volts DC proportional to 0 to 1,250,000 watts.

Special considerations: Since a motor is an inductive load one will see effects similar to those experienced with AC power because the voltage supplied from a six-pulse phase angle fired SCR controller is time varying. **Power is <u>not necessarily equal to</u> measured effective voltage X measured effective current.** The power will likely be less than the product of measured voltage and current and that difference will increase with increasing firing delay. Remember that the current drawn by an inductive load will lag the voltage. The power measured by the PC8 watt transducer will, within its accuracy rating, be the correct value.

In both examples the Hall effect current transducer is supplied with the watt transducer.

If you have any question or comments, please contact Ohio Semitronics, Inc.

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