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Power Analysis

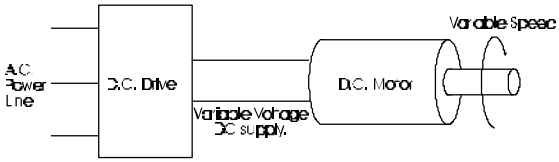
Making Measurements on PWM Drives

What is a PWM Drive?

Nowadays a PWM (Pulse Width Modulated) drive, used with an ac motor, is the economical way of producing a motor system with variable speed.

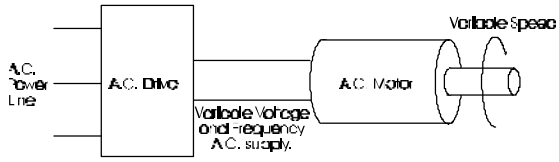
DC Motor

- Traditional motor for variable speed,
- Simple variable voltage / resistance control,
- Complex mechanical construction,
- High maintenance costs.

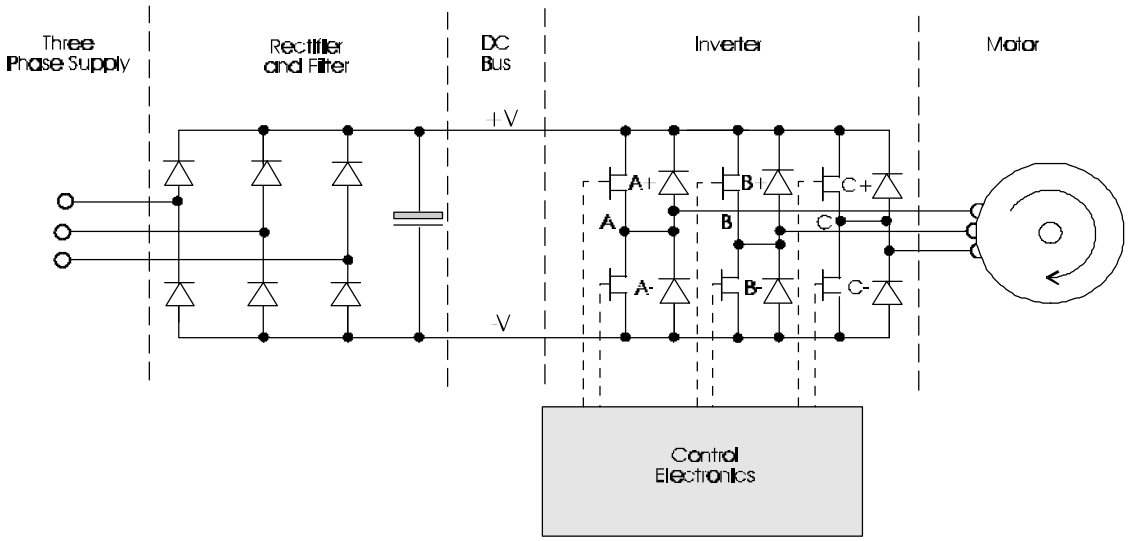


AC Motor

- Simple mechanical construction,
- Low maintenance costs,
- Variable speed requires a complex drive, with variable voltage and frequency,
- Traditionally used in fixed frequency applications.

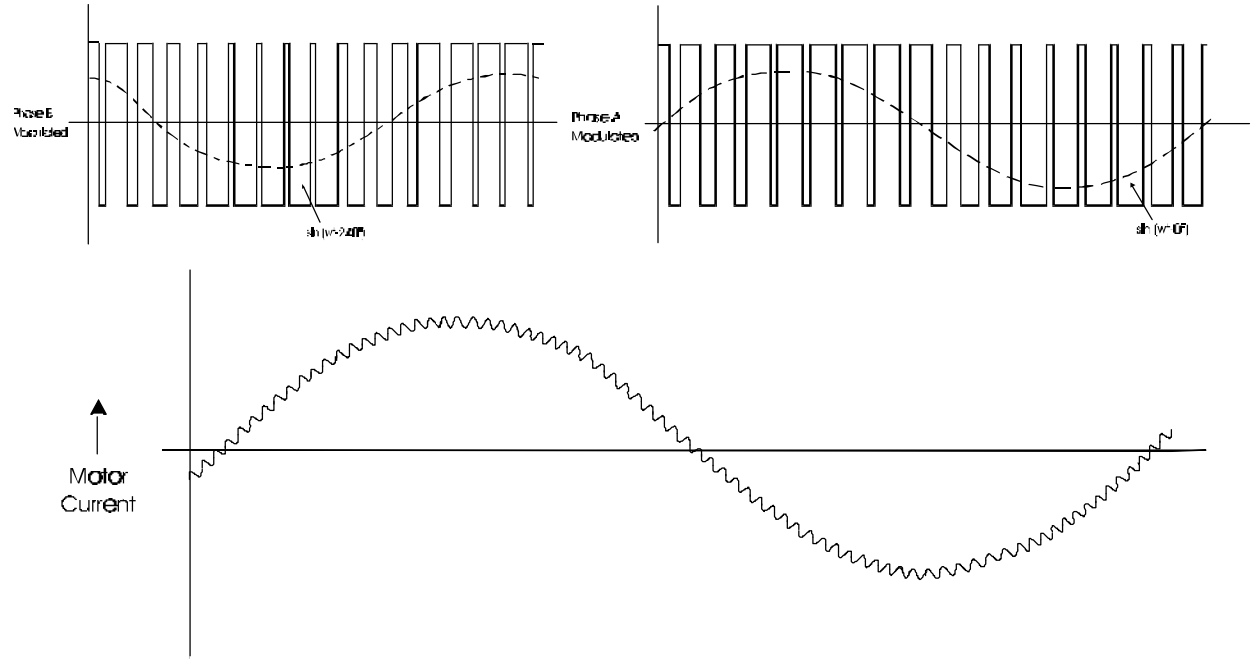


With the advent of low cost power semiconductors, capable of high speed switching, the variable voltage and frequency control required by the ac motor is easily achieved using the technique of Pulse Width Modulation. The following diagram shows the main components of a typical PWM drive:



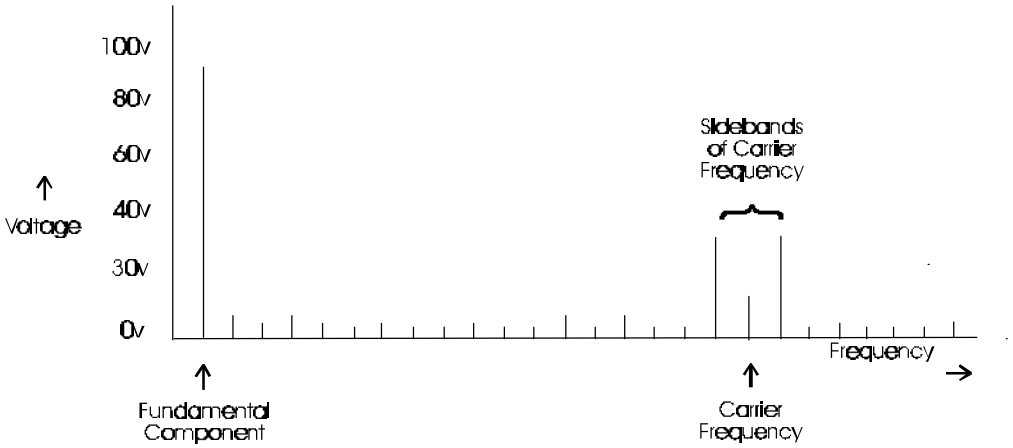
PWM Waveforms

The output voltage from a PWM drive the complex waveforms shown below:



Each voltage phase is a series of high frequency pulses, which have a fixed period, but a width that is variable and changes at different points in time. Changing the pulse width allows the average voltage output for the duration of the pulse to be varied linearly from 0V (pulse width 50%), to either positive (pulse width > 90%) or negative (pulse width < 10%) extremes. Typically the modulation is sinusoidal, producing three phases at the required motor speed, as shown in the figure above. Note that the modulation may be controlled to vary both the voltage and the frequency of the drive independently.

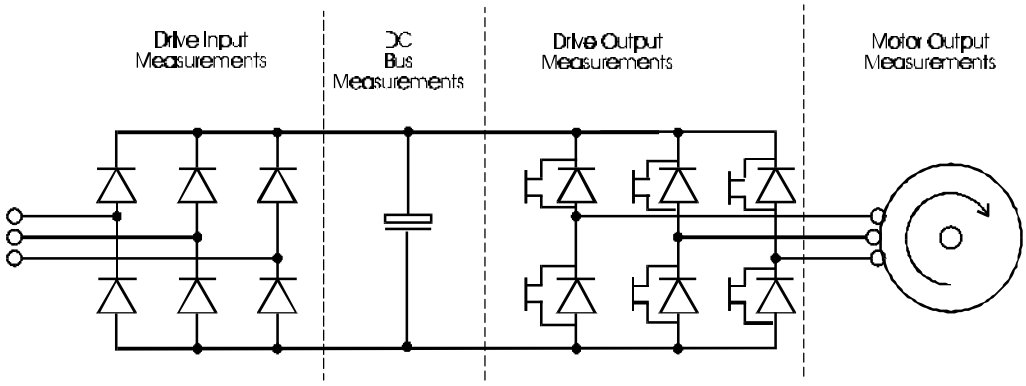
Clearly each voltage phase contains a signal at the required motor frequency; but is also contains a number of other frequencies related to pulse switching frequency. The following figure shows the spectrum of a typical drive output:



The current signal shown above is not as complex as the voltage signal because the inductance of the motor acts as a filter to remove some of the high frequency components.

Power Measurements Required on PWM Drives

The following table lists some of the measurements required to be made when testing a PWM motor drive.



Motor Output Measurements	Speed, Torque, Shaft Power
Drive Output Measurements	Total Output Power & Power Factor Fundamental Output Power & P F RMS Output Voltage and Current Fundamental Output Voltage and Current Harmonic voltages, currents & powers. Output Frequency
Drive DC Bus Measurements	DC Bus Voltage, Current and Power
Drive Input Measurements	Input Voltage and Current Input Power and Power Factor Input VA and VArs Input Harmonic Currents (including checking to harmonic specifications such as IEC555)
Efficiency Measurements	Efficiency of each section of PWM drive, motor efficiency and overall efficiency
Measurements Under Dynamic Load Conditions	Real time analogue outputs representing voltage, current, watts and power factor of drive output.

Motor Output Measurements

The Voltech PM3000A Power Analyzer is equipped with auxiliary inputs that you can connect to torque and speed transducers, allowing the PM3000 to directly read and display

- The rotation speed of the motor
- The (mechanical) motor output power
  - = Torque (Nm) ∗ Speed (radians / sec)
  - = Torque (Nm) ∗ Speed (rpm) ∗ (π / 30)

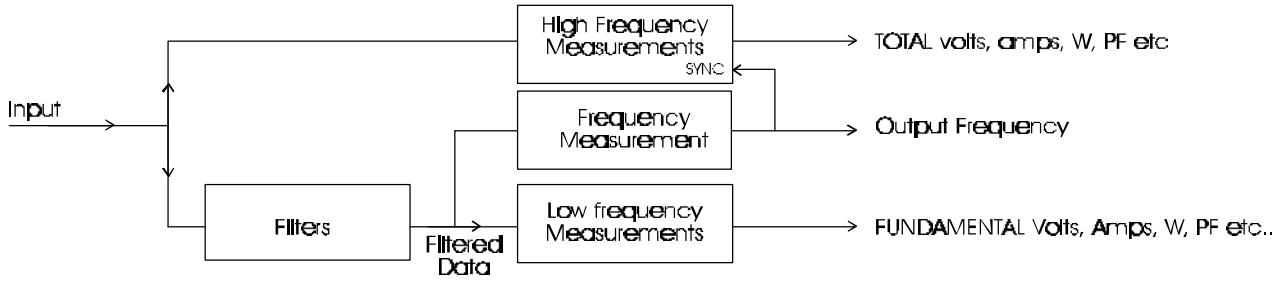
You may enter any scaling factor for the torque transducer, in either Newton-metres (Nm) or foot-pounds per Volt. The frequency input may be digital, as a series of pulses, or as an analogue voltage.

Drive Output Measurements

The output waveform of a PWM drive is a complex mixture of high and low frequency components, which most power analyzers find difficult to measure accurately. This because they either measure at high frequencies, in which case the low frequency content of the waveform is lost, or they filter the waveform to measure at low frequencies, in which case the high frequency data is lost.

A particular difficulty is measuring the total power, which must be done by sampling at a high frequency (to include the high frequency content of the waveform), but over an integral number of cycles of the motor frequency.

The PM3000 overcomes these measurement problems by using a special operating mode for PWM output measurements. The data is sampled at high speed, and parameters such as the total Vrms and Watts are computed in real time. At the same time, the samples are digitally filtered to provide the low frequency measurements such as the fundamental voltage and current, and a measurement of the output frequency.

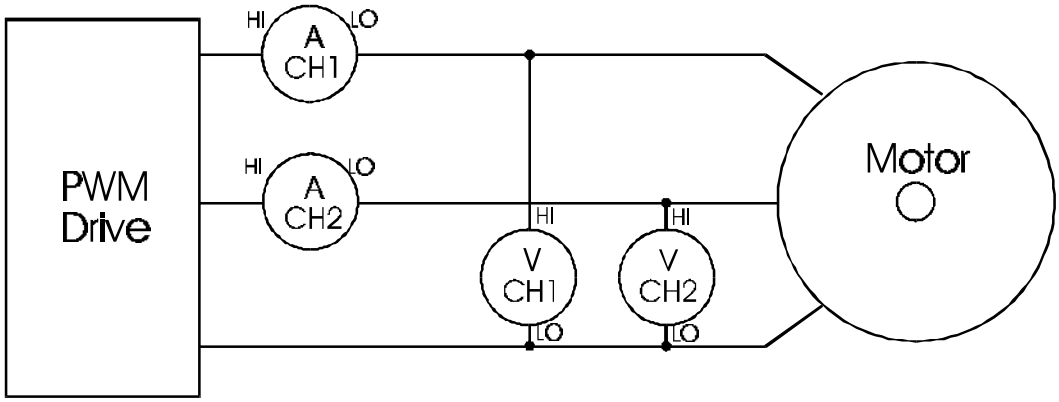


This technique allows both high frequency and low frequency data to be obtained from the same samples, and allows the high frequency measurements the be synchronised to the low frequency signal.

The PM3000A allows you a choice of three filters, selected according to your motor speed:

Filter	Application	Update rate
5.0Hz to 1000Hz	PWM Drives down to 5Hz output	400ms
0.5Hz to 25Hz	Low speed measurement down to 0.5Hz	4s
0.1Hz to 25Hz	Very low speed measurement down to 0.1Hz	16s

To make the actual drive output measurements, you can connect the PM3000A using the 'two wattmeter' method:

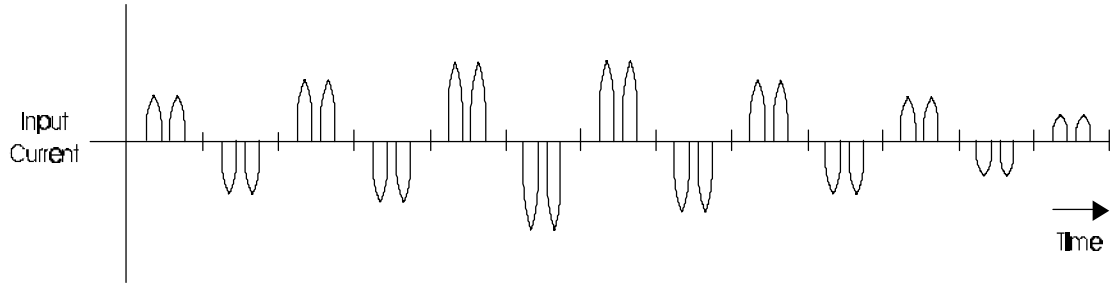


This leaves one channel free for example to make the measurement on the DC Bus.

Input Measurements

The input circuit to many PWM drives is essentially at three-phase diode rectifier and capacitor. The input current to such a circuit would normally be a series of pulses, each occurring at the time of re-charging the capacitor on a peak of the voltage waveform.

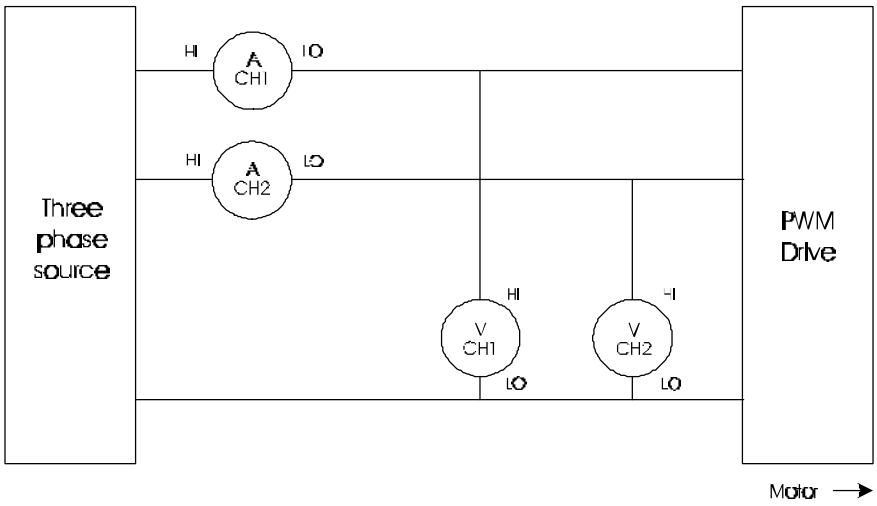
However, a PWM drive does not always present a constant load, and therefore the current taken from the supply will be modulated by components of the output frequency.



Again this complex waveform can present problems to many power analyzers.

In contrast, the PM3000 has a special operating mode for measuring the input power to a PWM drive. In this mode, measurements are synchronised to the ac line frequency, but made over a user specified interval of between 1 and 10 seconds, which is an integral number of cycles of the output waveform.

To make the drive input measurements, you can again connect the PM3000 using the ‘two wattmeter’ method:



Again this leaves one channel free for example to make the measurement on the DC Bus.

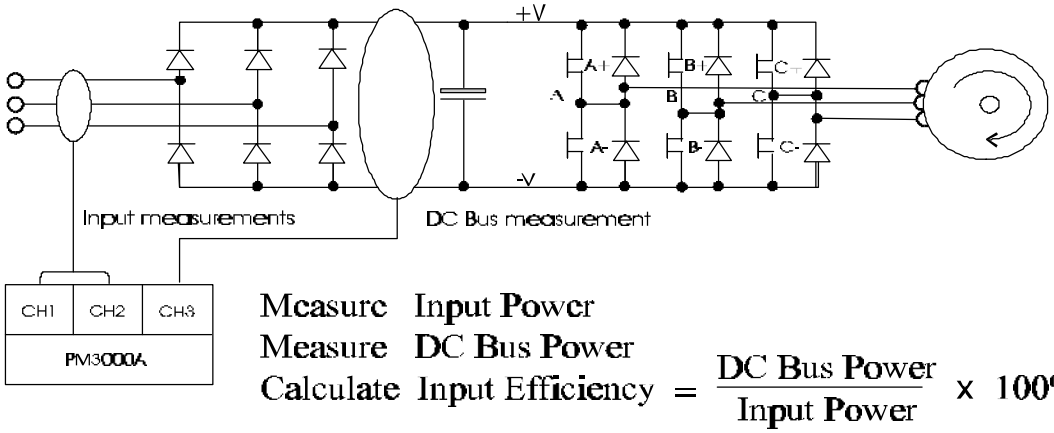
Efficiency Measurements

Generally on any system, the efficiency is calculated from simultaneous measurements of the input and output power. With systems where the efficiency is high, such as PWM drives, it is particularly important that the measurements are simultaneous, because with sequential measurements there may be changes to the system during the time that it is shut down to transfer the analysers from input to output.

Drive Efficiency

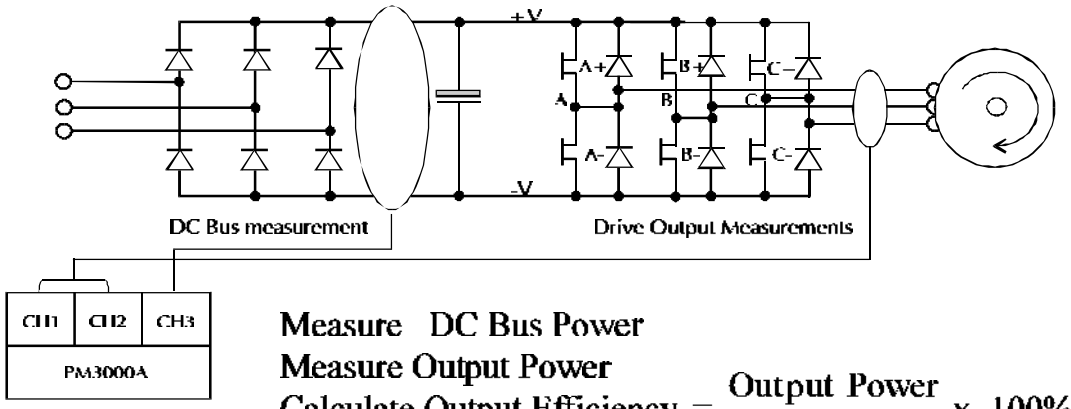
Although the PM3000 has three analyzers, it may still be used to make a series of simultaneous measurements allowing overall efficiency of the drive to be calculated.

Input Efficiency



Measure Input Power
Measure DC Bus Power
Calculate Input Efficiency $= \frac{\text{DC Bus Power}}{\text{Input Power}} \times 100\%$

Output Efficiency

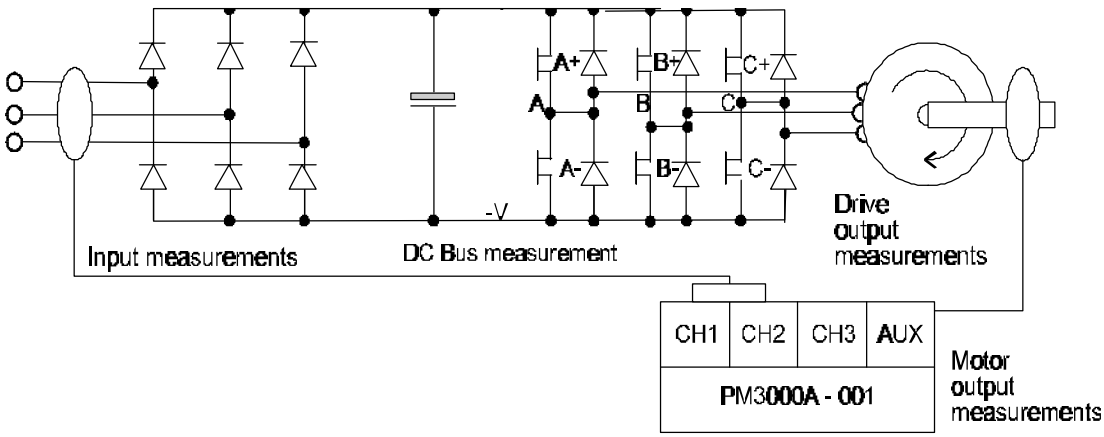


Measure DC Bus Power
Measure Output Power
Calculate Output Efficiency $= \frac{\text{Output Power}}{\text{DC Bus Power}} \times 100\%$

Overall Drive Efficiency = (Input Efficiency * Output Efficiency) / 100%

Overall System Efficiency

Alternatively, as the PM3000 has torque and speed inputs, the overall efficiency of the motor and drive system can be measured directly:



Measure Input power
Measure Mechanical Power

Calculate
Overall System Efficiency = (Mechanical Power / Input Power) * 100%

Summary

The Voltech PM3000A provides unique and easy-to-use measurement modes for use in PWM applications. This is just one of the many outstanding features of the PM3000A that make it ideal choice for motor and motor-drive measurements.

For more information contact your local supplier, see us on the internet at www.voltech.com or contact one of our main offices:

Voltech Instruments Inc.
11637 Kelly Road, Suite 306
Fort Myers.
FL 33908
USA

Ph. 239 437 0494
Fx. 239 437 3841
sales@voltech.com

Voltech Instruments Ltd.
348 Harwell Business Centre
Didcot, Oxfordshire.
OX11 0RA
UK

Ph. +44 (0) 1235 834555
Fx. +44 (0) 1235 835016
sales@voltech.co.uk