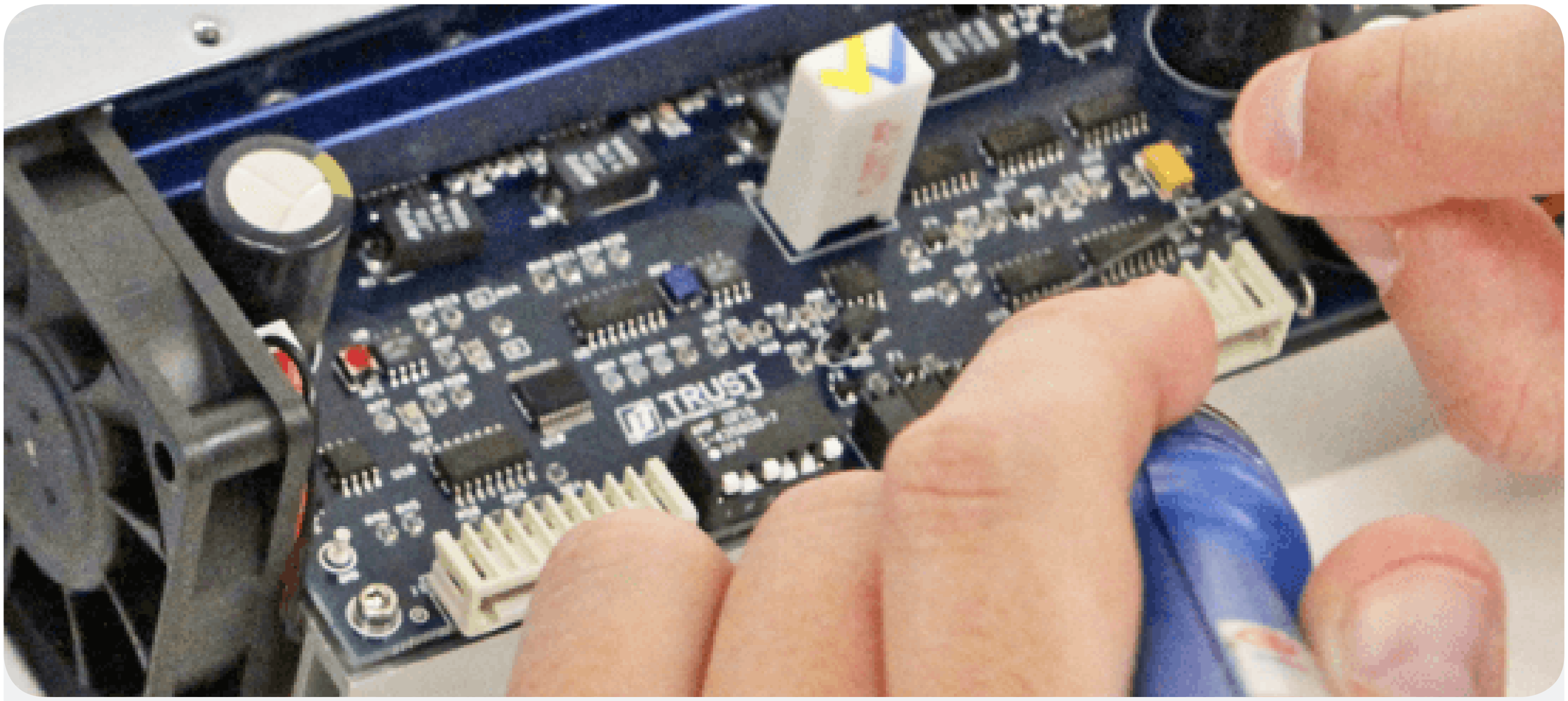


APPLICATION NOTE 125

LINEAR VS. PWM/ DIGITAL DRIVES

INTRODUCTION

Selecting the correct drive technology can be a confusing process. Understanding the difference between linear (Class AB) type drives and PWM or digital (Class D) type drives is necessary to determine the technology best suited for a specific actuator or application. Drives are often selected using only one criterion, which may lead to performance or system characteristics that are not optimized for all applications. This application note addresses the difference between linear drive technology and PWM drive technology.

BASIC TECHNOLOGY DIFFERENCES

In the past, many brands of linear drives or amplifiers were only Class C-rated. All Trust Automation drives are Class AB-rated. It is important to understand the differences between Class AB, Class C and Class D drives. See the table below for a simple comparison:

Class AB	Trust Automation's standard linear drives
Class C	Many older designs for linear drives
Class D Analog	Trust Automation's custom PWM drives
Class D Digital	Traditional AC servo drive

TYPE OF DRIVE	LOW EMI/RFI	NO DEAD BAND AT ZERO CROSSING	HIGH BANDWIDTH CURRENT LOOP	HIGH EFFICIENCY
Class AB	X	X	X	
Class C	X			
Class D Analog		X	X	X
Class D Digital				X

When evaluating the different technologies, it is important to understand the categories being compared above. The following summarizes these categories and why they are important in machine design.

LOW EMI/RFI

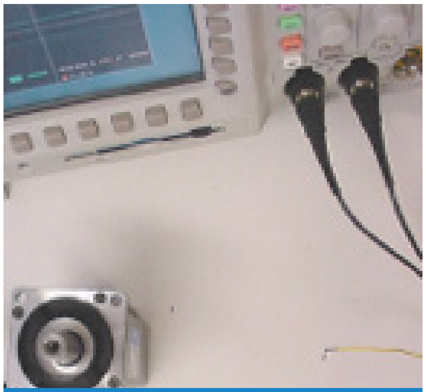
The majority of modern machinery relies on sensor technology to make process decisions. Most sensors use analog circuitry to evaluate conditions and will either pass this analog signal back to a host computer system for evaluation, or the sensors will perform the evaluation and pass the decision back to the host. Class AB linear drives do not have EMI or RFI noise emissions, improving process throughput and reducing wiring problems in production machines.

Understanding this concept is important because these low-level signals are very susceptible to EMI/RFI noise. Signal or clean power cables that pass near motor cables or are attached to the machine chassis can pick up this noise very easily. Once the noise gets into the sensor signals, it will diminish overall system performance.

Performance will be degraded because filtering is required in order to remove or reduce the effect of the noise. Filtering always reduces the speed of the circuit. In many cases, this can slow down the acquisition time of a sensor by more then 25 times, resulting in reduced performance and slower throughput of the end process.

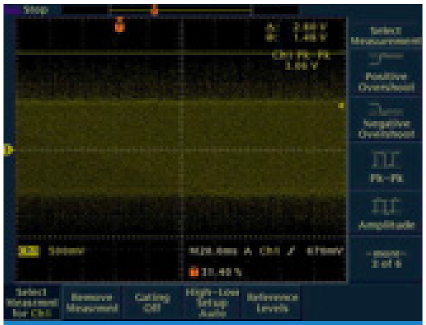
Noise is also a factor in stable machine operation. Noise will transmit through the air to other control wires and, in many cases, where the control signals are low voltage. The magnitude will be smaller than the original signal on the transmitting side but can still be very large due to the high voltage at which many digital AC servo systems operate. The example below illustrates these properties. (More information is available in Application Note 110.)

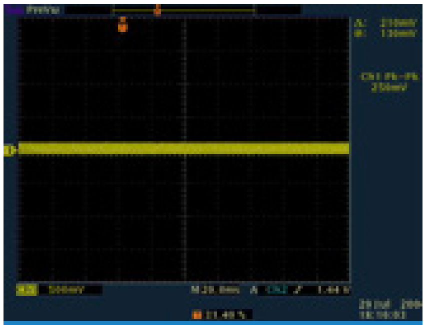

BLUE TEST WIRE AROUND MOTOR CABLE

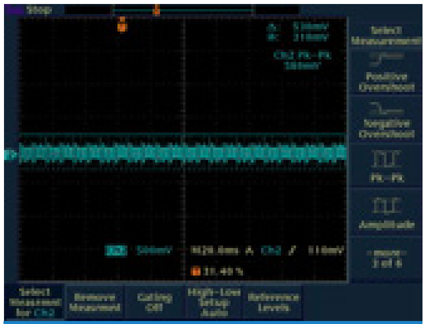

PICKUP PLATE 100MM FROM MOTOR

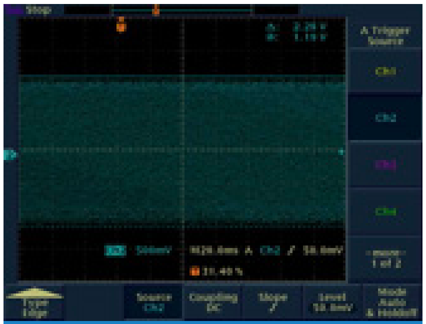

ANOTHER VIEW OF 10X10MM PICKUP PLATE

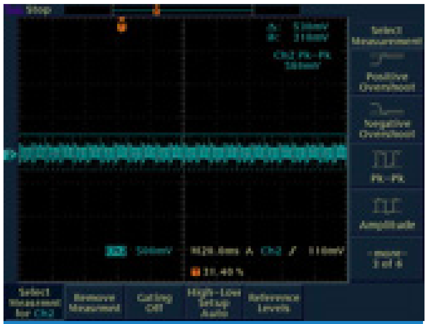

BASELINE NOISE ON BLUE WIRE


YASKAWA SGD DRIVE 30% POWER


TA310 DRIVE 30% POWER

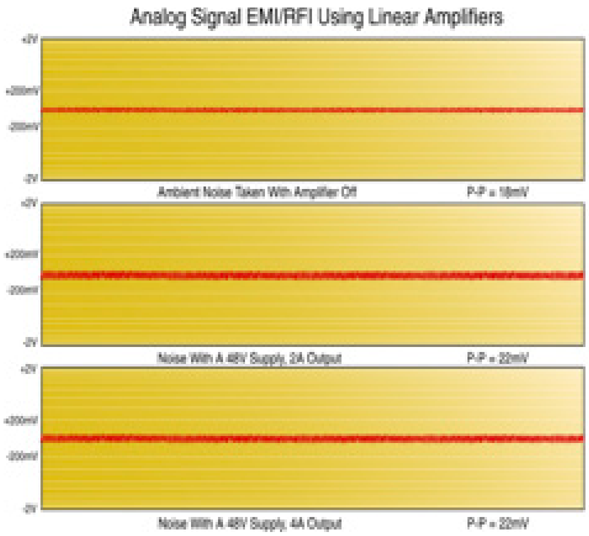

BASELINE NOISE ON YELLOW PLATE

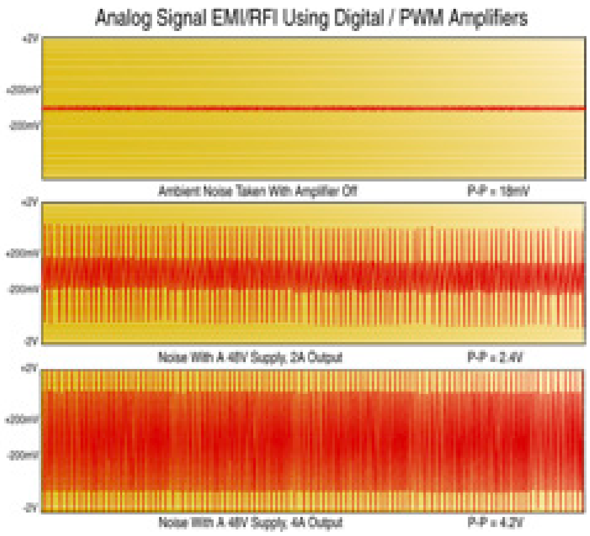

YASKAWA SGD DRIVE 30% POWER


TA310 DRIVE 30% POWER

A less obvious benefit of using linear drive technology is the ability to use a simplified wiring scheme. The lack of EMI/RFI created by linear drives allows the developer to run motor and sensor cables together in the same cable tracks. This greatly reduces the extra hardware and effort required to manage and control ground loops and ground points for all aspects of the machine that come in contact with either the drives or the motors.

The following charts illustrate additional testing showing graphical representation of noise comparisons between AC Digital Drives and Linear Drives.


Analog Signal EMI/RFI Using Linear Amplifiers


Analog Signal EMI/RFI Using Digital / PWM Amplifiers

NO DEAD BAND AT ZERO CROSSING

The ability of a stage to position at tolerances below 1 micron can be hindered by the Dead Band at the Zero Current Crossing point in a drive. This also negatively affects settling times in precision applications (stages). Class AB linear drives have no Dead Band at the Zero Current Crossing, contributing to their high performance and very fast settling times.

Dead Band causes problems with precision staging and settling because it does not allow the drive to output low levels of current accurately near the zero-crossing point. On most applications, this is the point where the stage is trying to move to its final position or hold position without dithering in place. It is common to find stages using Class C or Class D digital drives performing poorly when the stage is stopped or decelerating to its final position. Good current output control at a low level is vital to maintaining correct relationships in the controllers' control loop equations.

When using a drive that exhibits Dead Band, the system cannot accurately control small or fine movements, resulting in long settling times. The stage may also buzz or dither in the stationary and holding positions.

Linear drive customers have seen an 80% reduction in settling times on some applications by switching from Class D drives to Class AB drives and immediately gain two important advantages:

1. ***Immediate improved machine performance.***
2. ***Reduced setup and tuning time during manufacturing installation, as well as scheduled maintenance.***

In one case, a customer who supplies inspection and assembly equipment to the disk drive industry reduced 8 axes of machine setup and tuning from two days to 30 minutes for an application requiring 100 nm-position and settling. This was accomplished by replacing all PWM drives with Class AB drives and updating the tuning parameters.

HIGH BANDWIDTH CURRENT LOOP

Current loop precision and speed is the biggest factor in velocity stability and the second biggest factor in stage settling and stability. Class AB drives have the highest performing current loops available of any drive type. The default factory settings are general, resulting in good performance across many types of motors. At Trust Automation, we also provide custom configurations, optimizing system performance for customer-specific applications. Trust recommends testing drives in their default setting before making custom requests. 95% of our customers use the default settings, however, current loop bandwidths greater the 5 kHz can be achieved by matching to a specific motor.

Current loop bandwidth needs to be compared equally between technologies. This is important both at low speeds and high speeds. Class C drives perform well between 1 and 2 kHz. Above 2 kHz, the Dead Band begins to distort the small and large signal current waveforms, compromising motion and system performance.

Class D AC servo drives have limitations with both small signal response and high performance. The small signal performance of AC servo drives is limited due to the resolution limit of the control IC PWM generator. Class D AC servo drives typically use 8- to 10-bit resolution for their current control, totaling 256 to 2,048 discreet current steps between full reverse and full forward motor control. This is caused by the need to keep switching frequencies as high as possible—usually 20 kHz or higher. The resolution and switching frequency of a Class D drive is easy to calculate. Simply divide the control IC base frequency (typically 20 to 50 MHz) by the switching frequency.

50,000,000 / 20,000 = 2,500 possible steps between full reverse and full forward

The ratio stays locked no matter what. To increase the PWM frequency, you must decrease your possible steps. To decrease the PWM frequency, you must increase your possible steps.

50,000,000 / 40,000 = 1,250 possible steps between full reverse and full forward

Because available steps are limited, small signal performance is limited. However, high-performance staging applications require very good small signal performance. Another factor related to resolution and contributing to the small signal performance is line voltage.

Most AC digital drives are connected directly to either 100 or 200 VAC. This means that the actual DC voltage switching inside the drive is usually 144 to 288 VDC. The current is the voltage driven through the resistance of the motor windings. Take, for example, a 200 VAC-connected drive with 1,250 steps of resolution, assuming the motor has a 1 Ω coil.

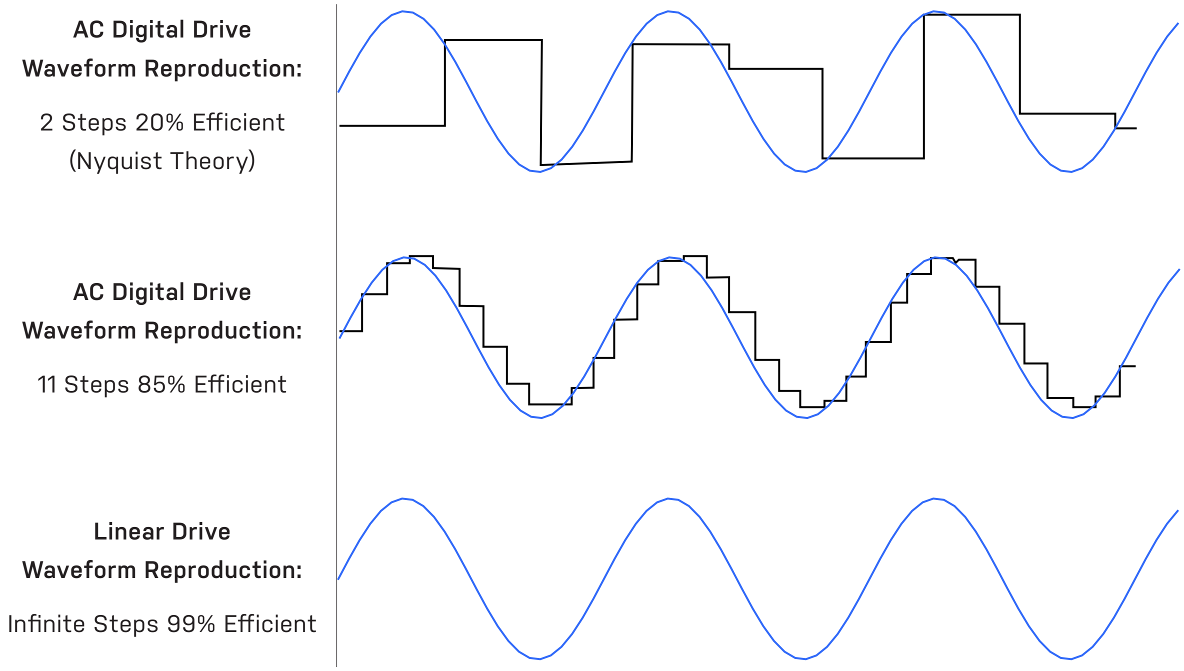
288VDC / 1,250 steps = 0.23 volts per step in a perfect setup

0.23VDC / 1Ω = 0.23 Amps per step

Many applications require less then 1 A to maintain steady state servo loop positioning. In this case, there are only five steps of control to maintain this positioning, resulting in stage dithering or buzzing due to the low resolution.

Most Class D AC servo drives have a true current limit bandwidth of less then 500 Hz. Most are actually closer to 200 Hz. Smooth motion, good stability and fast settling time requires accurate current loop bandwidth. It is possible to achieve approximately 85% accuracy of a waveform with eleven data points per waveform. The following diagram illustrates this principle:

CURRENT LOOP ACCURACY VS. EFFICIENCY



To accurately reproduce a waveform you need to have a minimum of eleven data points, meaning the current loop sampling needs to be eleven times the actual waveform frequency. This is why most AC digital drives have 200 to 500 Hz true bandwidth.

500 Hz * 11 data points = 5,500 Hz current loop.

Very often, digital drive manufacturers specify current loop bandwidth using the Nyquist Theory, which states you only need 2 data points to represent a waveform. This is true if the waveform accuracy you are trying to represent is not important.

The current loop technology differs greatly between Class AB linear drives and Class D AC digital drives. A Class AB linear drive current loop is entirely analog—and for good reason. An analog current loop provides two important characteristics:

1. ***An infinite number of steps between full reverse and full forward.***
2. ***A very fast current loop because it is not limited by the processor speed.***

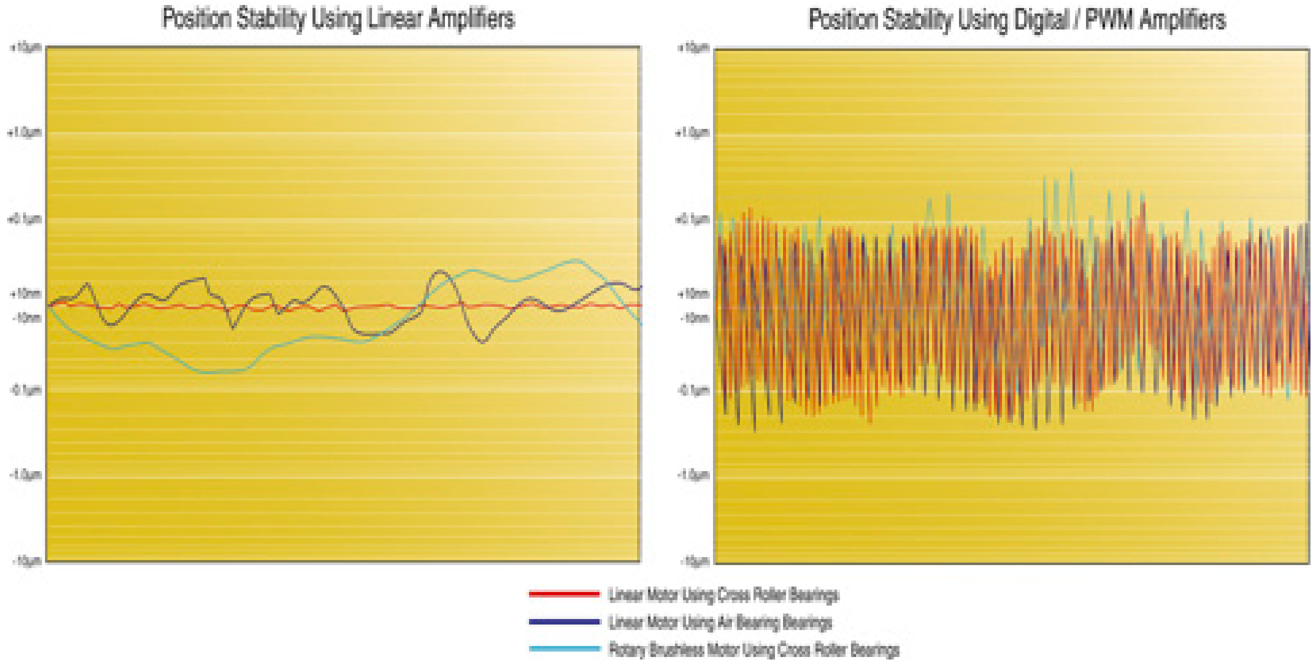
These attributes are advantages in high precision stage applications for several reasons:

1. ***The small and large signal resolutions and responses are very good.***
2. ***Waveform reproduction is extremely accurate.***
3. ***Input voltage does not affect system stability.***

All these items result in increased stability and faster settling times.

HIGH EFFICIENCY

The performance improvements seen with a Class AB linear drives come at the expense of efficiency. The Class AB drive stage needs to maintain small amounts of power inside the drive circuits, resulting in increased heat. Also, due to the nature of a Class AB drive stage, excess voltage not needed by the motor is dissipated as heat. As a result, linear drives usually integrate large heat sinks to keep the drive components at a reasonable and specified operating temperature.



SUMMARY

The factors discussed in this paper will help you determine if linear or PWM drive technology is better suited for your application. Trust Automation is the leader in high-precision staging drives because of the attention given to the accuracy of signal reproduction, Zero Dead Band and high-quality analog design using precision-matched parts and high-performance components. These factors will help linear drive users achieve high precision with fewer concerns and problems typically associated with high-precision staging systems.