USITT Kansas City, 2010 – Automation 101 - Terminology

WARNING:

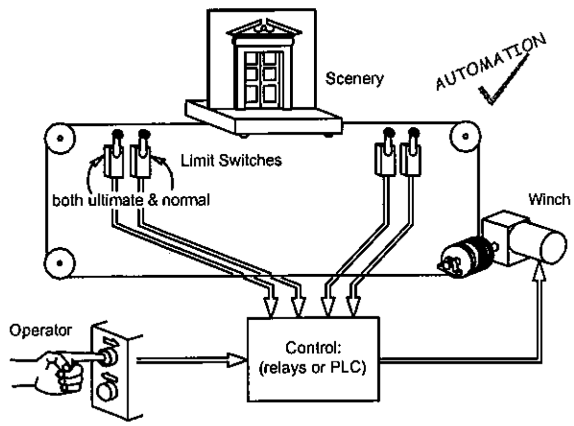
Moving scenery can create life-threatening situations. Safeguards appropriate to the hazards involved must be provided. Each application must be engineered for proper safety, be built "...in a neat and workmanlike manner" and run by qualified operators. What follows is a general discussion of scenery automation, and as such cannot address every safety issue.

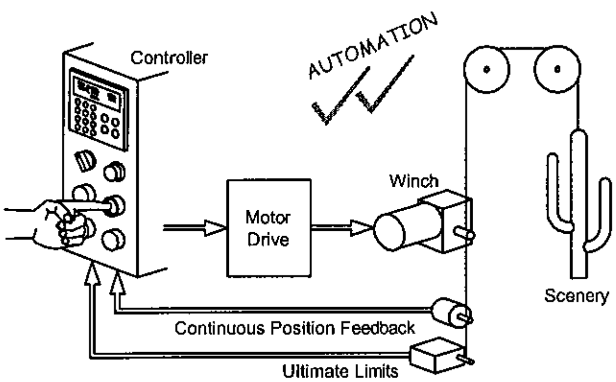
This session is aimed at TDs and others that are technically designing show specific installations of stage machinery, a scenic wagon or turntable for instance. This session will give an overview of the typical terminology of theatre automation, but it is a large and rapidly growing field, and so is by no means all inclusive. First a definition:

- **Stage automation** uses machinery, control equipment, and feedback components to automatically control the movement scenery in some way, most typically its speed and/or position.

The goal of automation is always to support the artistic vision of the director and set designer, providing artful, aesthetically pleasing movement. The means of achieving this goal involves mechanical, electrical, and electronic engineering, often with a heavy dose of computer science.

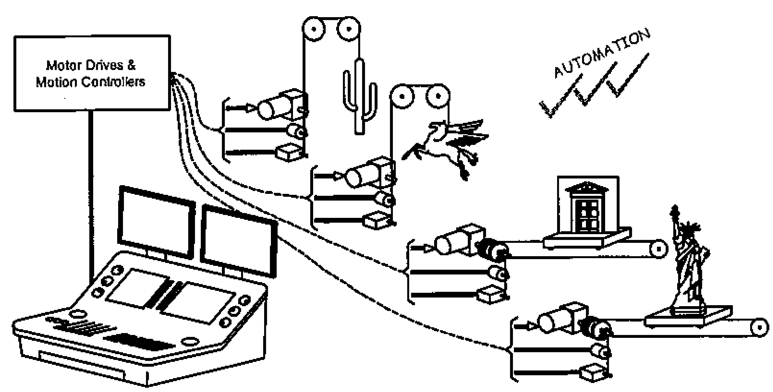
Stage automation covers a wide range of techniques. Control may be as simple as some pushbuttons wired to a reversing motor starter running scenery between limit switches ➔





🡐 A more complex automation system will use encoder feedback to continuously monitor the position of the scenery to enable the control system to decelerate the load to the exact position required.

The most complex systems today will simultaneously control dozens of axes of motorized scenery, all moving in perfect synchronization, consistently within known times, and with great safety. ➔



Some of the terminology used to describe the parts and operation of these diverse systems is the topic of this session

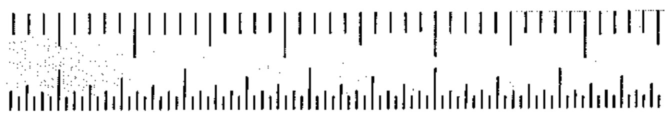
• **Feedback** is the process in which part of the output of a system is returned to its input in order to regulate its further output. (from: http://wordnetweb.princeton.edu/perl/webwn?s=feedback)

Many common devices use feedback: A thermostat, cruise control in a car, and the tank refill function of a toilet. Feedback in stage automation can be used to allow the control equipment to help insure that variables such as speed, position, torque, or pressure are held to operator specified values—or in short, that a move is consistently what you want it to be. While something as simple as a limit switch provides useful feedback information, position is usually measured using encoders.

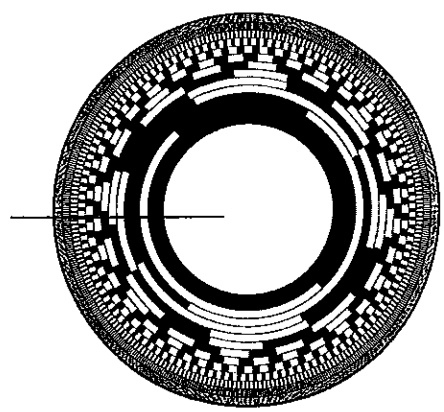
• **Absolute & Incremental** are two methods of measurement.

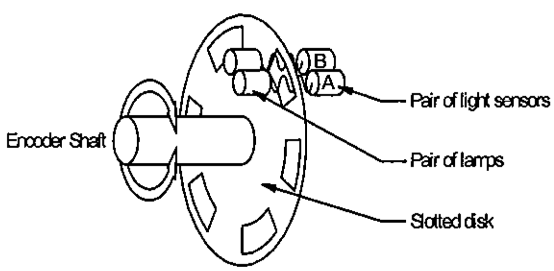
Absolute measurement is what you get off a tape measure. The end of the tape defines zero, and because of the numbering, with a glance any position on that tape is known distance from zero.

Incremental measurement is like a numberless tape measure. Any point can be defined as zero, and any position on that tape can be measured relative to that zero by counting the inches from zero to the position.



• **Absolute Encoder** An encoder that provides an exact unique position valve over some fixed range of movement from the instant it is powered up. The disk shown at the right has 12 tracks of binary information. At any position over one revolution of this disk sensors can read off a 12 bit number that represents that position, for instance 0100 1101 1011 1010 binary = 19898 decimal. Some stage automation systems use absolute encoders, though not the majority.

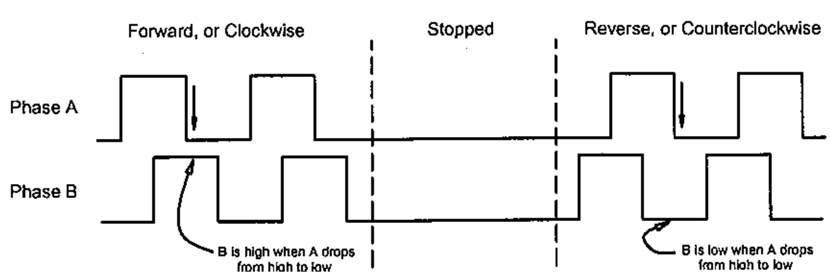




• **An Incremental Encoder** uses a disk with a pattern of holes at its edge. Sensors detect the holes (or lack of holes) and provide pulses as the encoder shaft spins. A pair of sensors is usually used so that the direction of rotation can be detected by associated electronics from the patterns of pulses that result.

• **Quadrature** is the signal coming from an incremental encoder with two sensors offset 90° relative to each other and the cyclical pattern of holes in the disk.

QUADRATURE ENCODER OUTPUT:



The pulses created by incremental encoders must be counted to determine position., and on system power-up, the counter will have no idea where the scenery actually is. A Home or zero position must be defined by running the scenery manually to a given spike position, and then setting the counter to the associated position value: 0, 10 ft, or – 2.4 m for example (the real units listed here would have to be converted from the raw pulse counts). It is the capacity of the counter that determines how many individual positions can be resolved:

- A 16 bit counter: $2^{16} = 65{,}536$ unique positions
- A 32 bit counter: $2^{32} = 4{,}294{,}467{,}296$ unique positions

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• Stop Categories, as defined by NFPA 79

- "**Category 0** is an uncontrolled stop by immediately removing power from the machine actuators." (9.2.2.1)
- "**Category 1** is a controlled stop with power to the machine actuators available to achieve the stop them remove power when the stop is achieved." (9.2.2.2)
- "Category 3" is as Cat. 1 but with power left on after the stop.

• Emergency Stop:

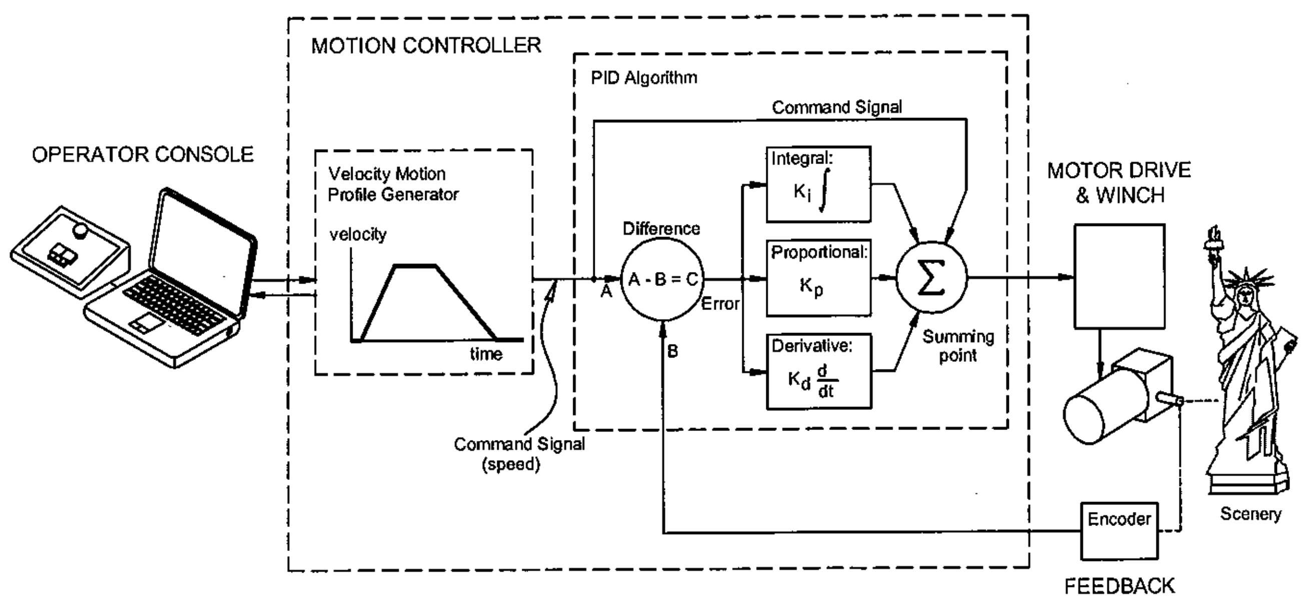
- "The emergency stop shall function as either a Category 0 or a Category 1 stop. The choice of category … shall be determined by the risk assessment of the machine." (9.2.5.4.1.3)

• Dead Man Control/Hold-to-Run Control:

- A control that must be held while motion is occurring. These controls are common on European automation systems because standards there have long required them. In this country there has been a long tradition of latching controls—the function stays on by itself until a move finishes—but as standards evolve here, expect to see dead man controls on all automation.

• Motion Controller

A motion controller is a device designed from the ground up specifically to control motion. Used in general industry to control milling machines and CNC routers, motion controllers provide a high level of precise control. On the flip side, they may be more complex than is needed in some applications.



Motion controllers take in a move's information from an operator console, also called an HMI (human machine interface). A cue's worth of information may include a target position, top speed, acceleration and deceleration times, and total run time. The controller uses this info to generate a velocity motion profile, basically a graph of speed versus time. When the cue is run, the controller uses feedback to monitor how closely the actual scenery movement is following the ideal motion profile. Differences, or errors, between real and ideal are fed into a mathematical algorithm called usually just "PID". This stands for proportional, integral, derivative. In a process called tuning, done during a system trial set-up, values are set that determine how much each of these components will affect the speed signal sent out to the motor:

P sets how much the error signal, just as it is, is sent out on to the drive
I sets how much of the effect of the error accumulating over time is sent off to the drive
D sets how much of the effect of rapid changes in the amount of error is sent off to the drive

The tuning process takes time, knowledge of the effects of these factors, and can be frustrating at times. Some manufacturers of motion controllers offer auto-tuning software to help ease this process. The payoff for the complexity of this process is that multiple axes of automation can be run in near perfect synchronization to each other—two lifts, for instance, can act independently, or act together as if they were one.

• Some **Codes and Standards** applicable to stage automation

United States:

- National Fire Protection Association:
  - NFPA 70, National Electrical Code
  - NFPA 79, Electrical Standard for Industrial Machinery
- Underwriters Laboratories: UL 508a, Standard for Industrial Control Panels
- Entertainment Services and Technology Association: *Draft* Standard BSR E1.6-1, Entertainment Technology – Powered Hoist Systems

European:

- CEN Workshop Agreement CWA 15902-1:2008, Lifting and Load-bearing Equipment for Stages and other Production Areas within the Entertainment Industry, Part 1: General Requirements (excluding aluminum and steel trusses and towers)
- Berufsgenossenschaft Regulation, BGV C1, Accident-Prevention Regulation for Staging and Production Facilities for the Entertainment Industry

• Bibliography

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- Alan Hendrickson, Colin Buckhurst, *Mechanical Design for the Stage*, 2008, Focal Press
- Anton Woodward, *Stage Automation*, 2008, Entertainment Technology Press