The Operator Training Committee of Ohio, Inc.

Level Control Methods and Explanations for Common Electrical Control terms

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A Quick Florida Joke!

Control Topic # 1

Level Sensing Options

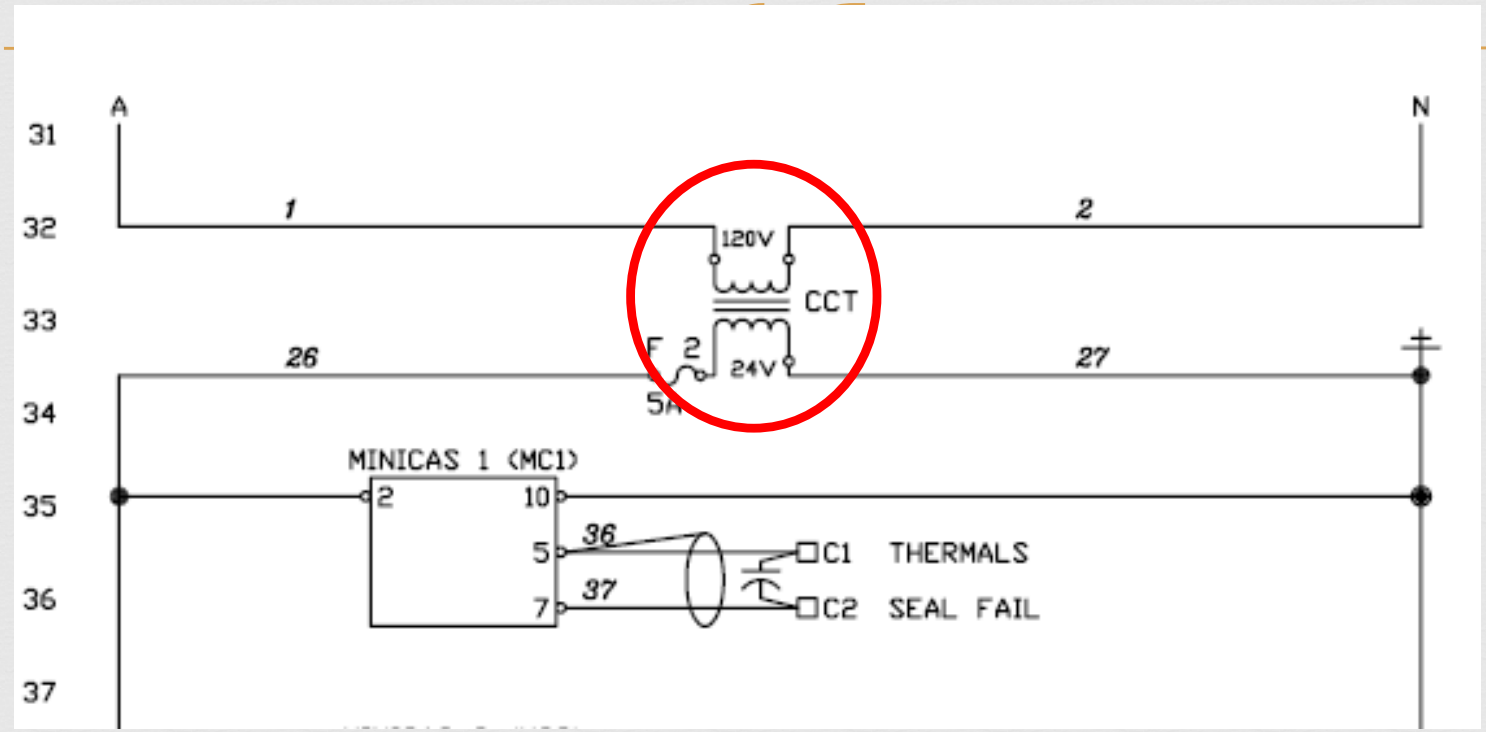
Level Sensing Options

- FLOAT SWITCHES
- BUBBLER SYSTEMS
- PRESSURE TRANSDUCERS
- ULTRASONIC TRANSDUCERS
- LEVEL PROBES

Float Switches

- Simplest operation
- Normally open or Normally closed
- Durable
- Reliable

Control Transformer



It's a Safety thing !

24V Transformer for Floats

- Skin Resistance varies from 100k to 1M Ohms when dry, to 1k Ohm or less if wet or sweaty
- Skin resistance varies with cleanliness, dampness, grip
- A wire held by hand would see 15k to 50k Ohms dry, and 3k to 5k Ohms wet

24V Transformer for Floats

- 120V / 15k Ohms = 8 mA
- 120V / 3k Ohms = 40 mA

- 24V / 15k Ohms = 1.6 mA
- 24V / 3k Ohms = 8 mA

- 24V is definitley better, but could still hurt you.

Current vs. Reaction

- 1mA - You can feel the current
- 5mA – Typical GFI Operation
- 5mA to 10mA hurts
- 16mA - A 175 lb. person can't let go
- 65mA - Heart Fibrillation that could be fatal if no one is there to help you

Advantages of Float Relay Logic

- Simple and rugged
- Allows for "shotgun approach" to troubleshooting
- Easy to implement pump delay by replacing Relays with Time Delay Relays

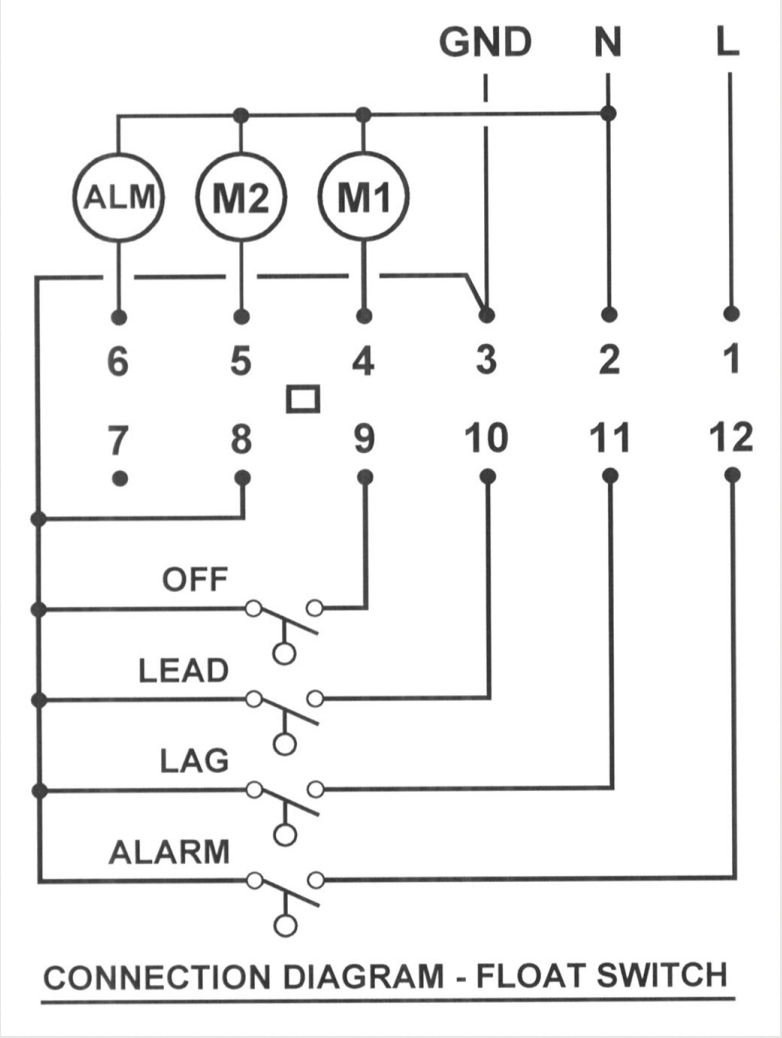
Disadvantages of Float Level Control

- Floats can get tangled
- Floats can become grease balls
- Disposal of Mercury floats (for areas still using them)

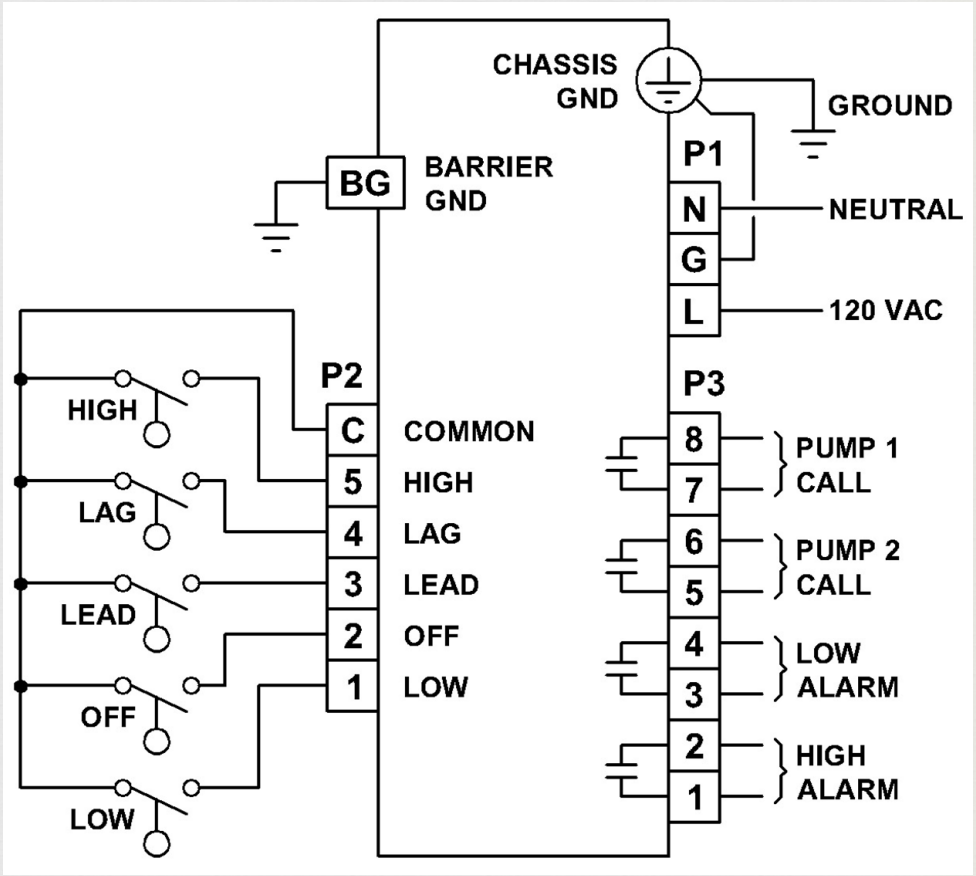
Float Controllers

- "Practically a panel" without the power train
- Most panel features included
- Remove and Replace if ever needed
- Simplest way to move a (small) Municipality to SCADA readiness

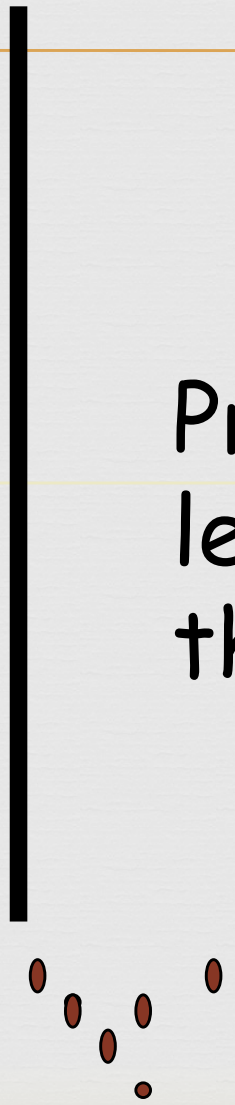
Float Controller



Float Controller



Bubbler Systems

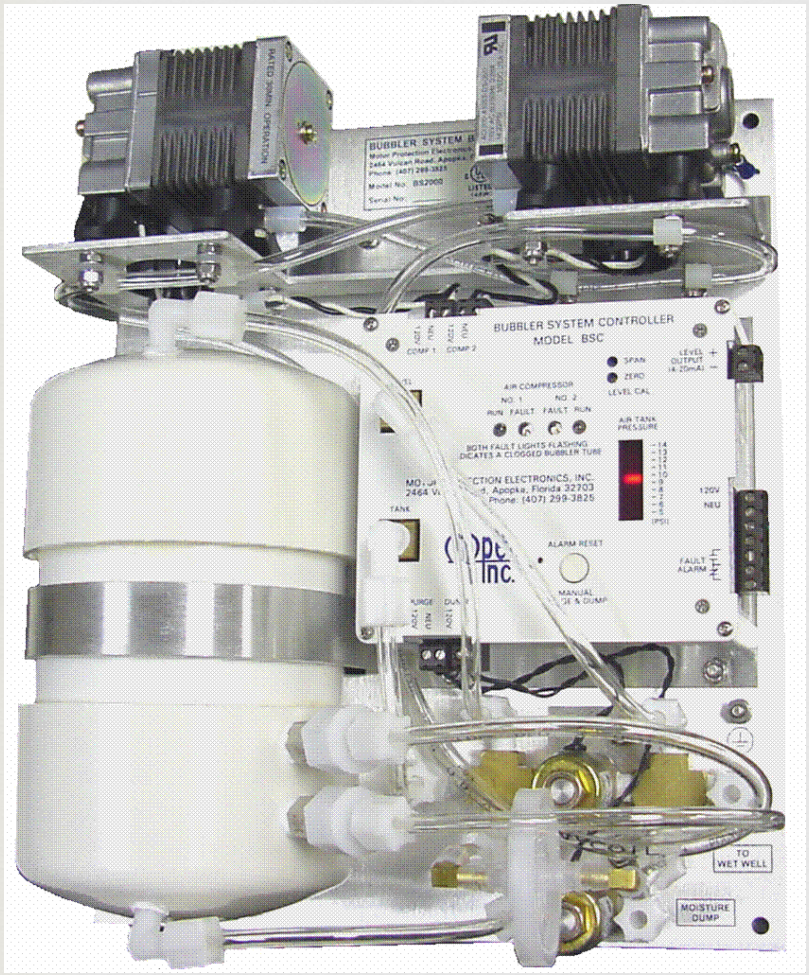


Pressure exerted on the liquid level is related to the depth of the water column

Bubbler Systems

- Not too much middle ground - people either love Bubblers or hate them
- Can be simple - fish tank aquarium pump and pressure switches
- Can operate as a level transducer and provide a 4-20mA level signal

Bubbler System with 4-20mA Output



- Modular design allows easy access to Air Compressor Assembly, Air Tank Assembly, Controller, and Solenoid Valve Assembly
- This type of a Bubbler System acts as Transducer, outputting a 4-20 mA signal

Advantages of Bubbler Systems

- Simple and cheap to do a basic Bubbler
- Not susceptible to lightning damage from the wetwell – (no metallic path from the wetwell to the panel controls.)

Disadvantages of Bubbler Systems

- Not a good application in cold weather if moisture is present –

  (Warm air condenses on a cooler surface)

- Most preventative maintenance intensive of level measuring devices – regardless of Bubbler type

Disadvantages of Bubbler Systems

- Typical failure modes are air leaks and air blockages
- Not a good application for use in heavy sludges

Submersible Pressure Transducer

AS WATER LEVEL INCREASES, PRESSURE ON THE FLEXIBLE DIAPHRAM INCREASES

Submersible Pressure Transducer

Submersible Pressure Transducers

- Most units are vented to Atmosphere
- Non-vented units available as well - (accurate except during a hurricane)
- Worst case atmospheric reading by NOAA was 25.68in-Hg - for a reading of 12.6 psi vs the standard 14.7 psi.

Submersible Pressure Transducers

- 14.7 psi - 12.6 psi = 2.1 psi
- 2.1 psi x 2.31 ft/psi = 4.85 feet
- The level reading would be low by 4.85 feet (for a relatively short period of time.)

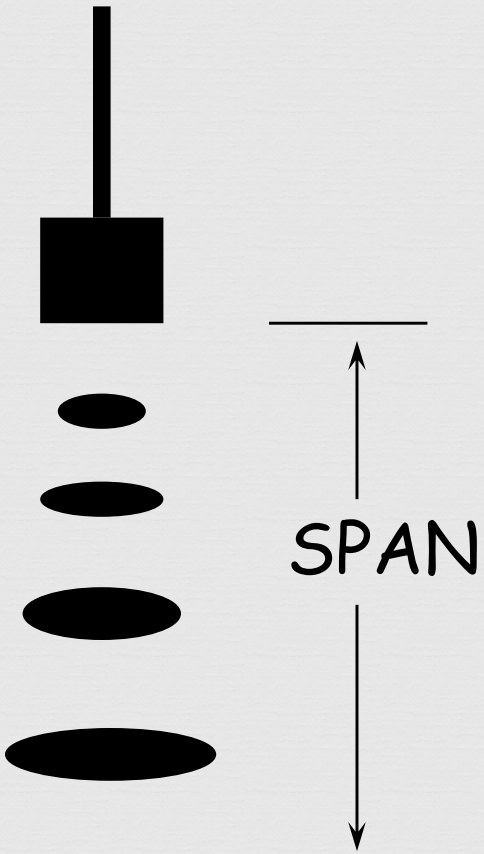
Submersible Pressure Transducers

- Advantages:
  - Rugged
  - Easy to install
  - Very Accurate

Submersible Pressure Transducers

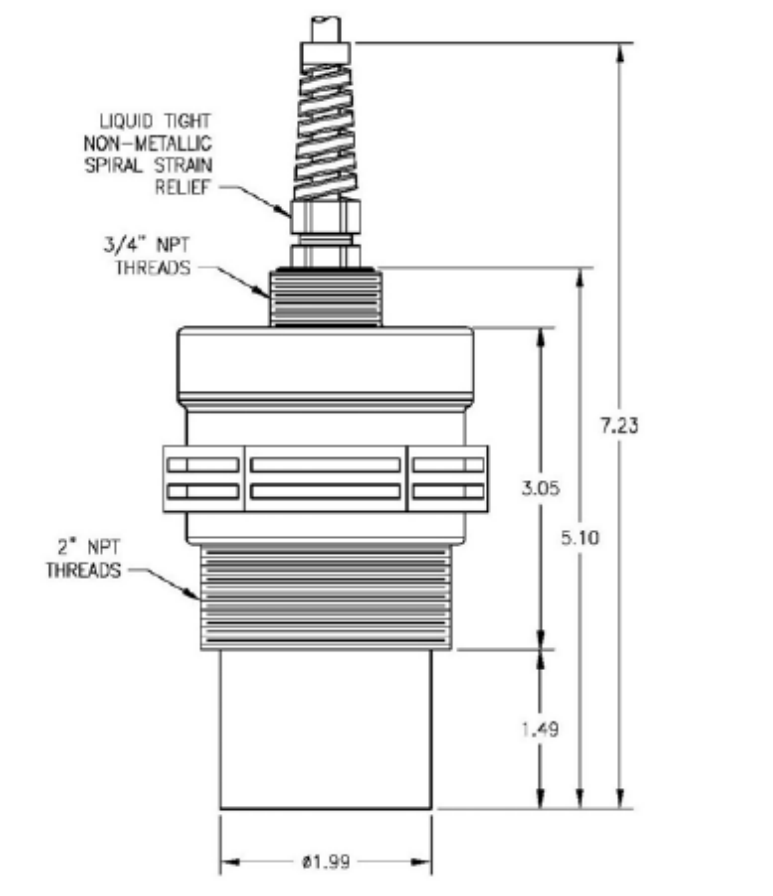
- Disadvantages
  - Units vented to Atmosphere prone to water intrusion over time (if air vent tube not properly protected)
  - Desiccant, Dryer, Breather Bag, Bellows unit – these need to be checked periodically

ULTRASONIC TRANSDUCERS



ULTRASONIC SENSOR MEASURES WATER LEVEL PROVIDING CONTACTLESS LEVEL MEASUREMENT.

Ultrasonic Transducer



Advantages of Ultrasonic Transducers

- Non-contact Level Measurement
- Good for Measuring Level of corrosive chemicals
- Good for Measuring Level in Shallow Applications

Disadvantages of Ultrasonic Transducers

- Incorrect Readings in high foam and Grease Build-up applications
- Does not measure well in highly agitated water
- Beam width becomes an issue as wetwell increases in depth
- Parameter setup is not intuitive

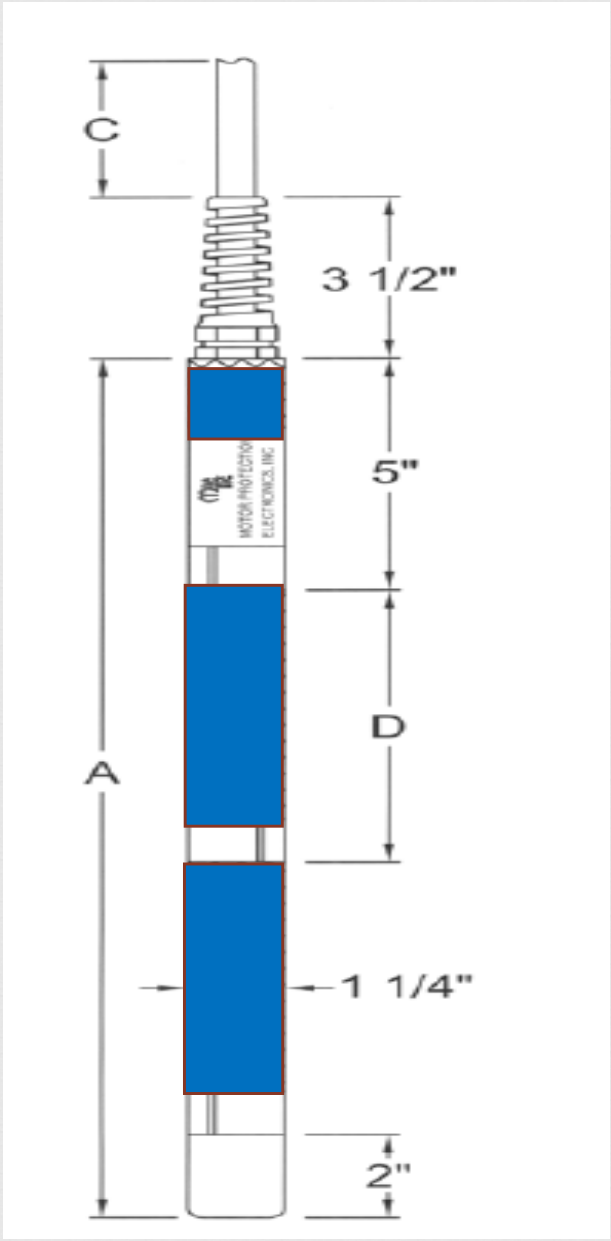
Level Probes

Conductance Devices - Controller supplies a +/- 12V waveform to each point on the Level Probe.

As the Probe sensor becomes submerged, the signal is conducted from the Probe, through the liquid, to ground.

Level Probes

- Simple installation
- Excellent in turbulent applications
- Excellent in grease, fat, or heavy sludge
- Low maintenance



Level Probes

- Probes available as Single Point, Three Point, and 10 Point Probes, but can be made with any number of electrodes up to 10.

Level Probes

- Probes available with 5, 6, 8, 10, and 12 inch spacings between electrodes

Level Probe Controls

Advantages of Level Probes

- Once installed, should last indefinitely
- Easy to set up using Level Probe Relays or Controllers
- Can be used with Barrier to provide an Intrinsically Safe Solution
- Turbulent water actually helps clean probe

Disadvantages of Level Probes

- Probes do require periodic cleaning
- For VFD applications, the 4-20mA output signal is a "stepped" output
- Not good for clean water and Stormwater applications - ion count!

Summary of Level Controls

- Floats
- Bubbler Systems
- Submersible Pressure Transducers
- Ultrasonic
- Conductance Level Probes
- A few others, but these are the most prevalent

Summary of Level Controls

- Rule of Thumb –

- While Level Measurement choice is often a matter of preference, one type of level control may not be the way to go for all applications!

Controls Topic #2

How to Properly Size a Submersible Pressure Transducer

Sizing a Submersible Transducer

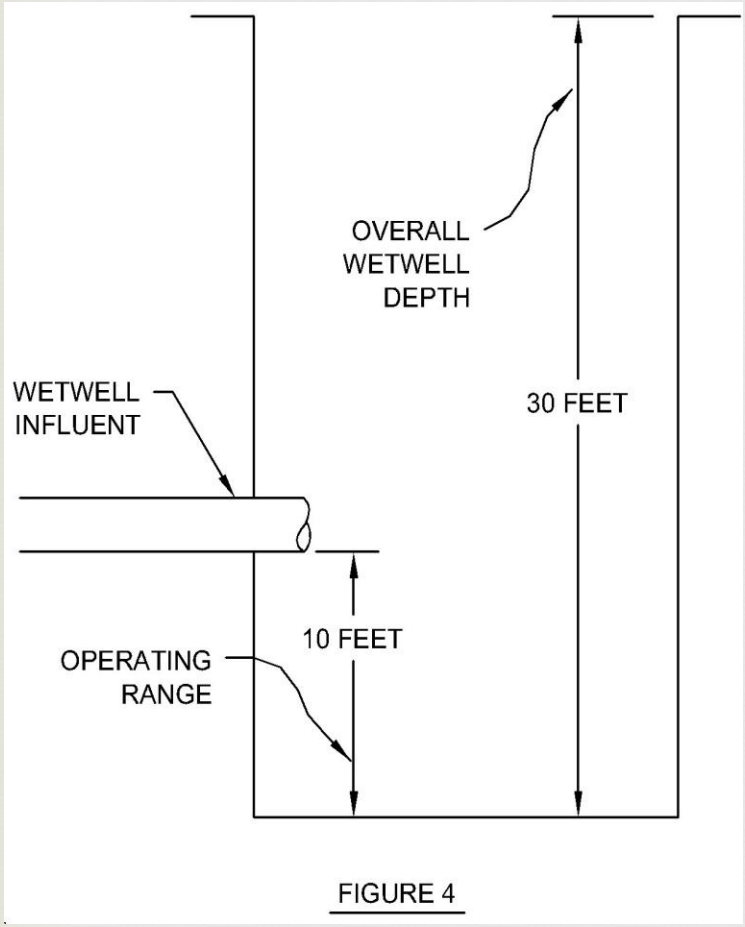


FIGURE 4

- The operating range of the wetwell is the key piece of information when sizing your transducer.
- If the level exceeds the operating range, you are backfilling your lift station's influent piping.

Sizing a Submersible Transducer

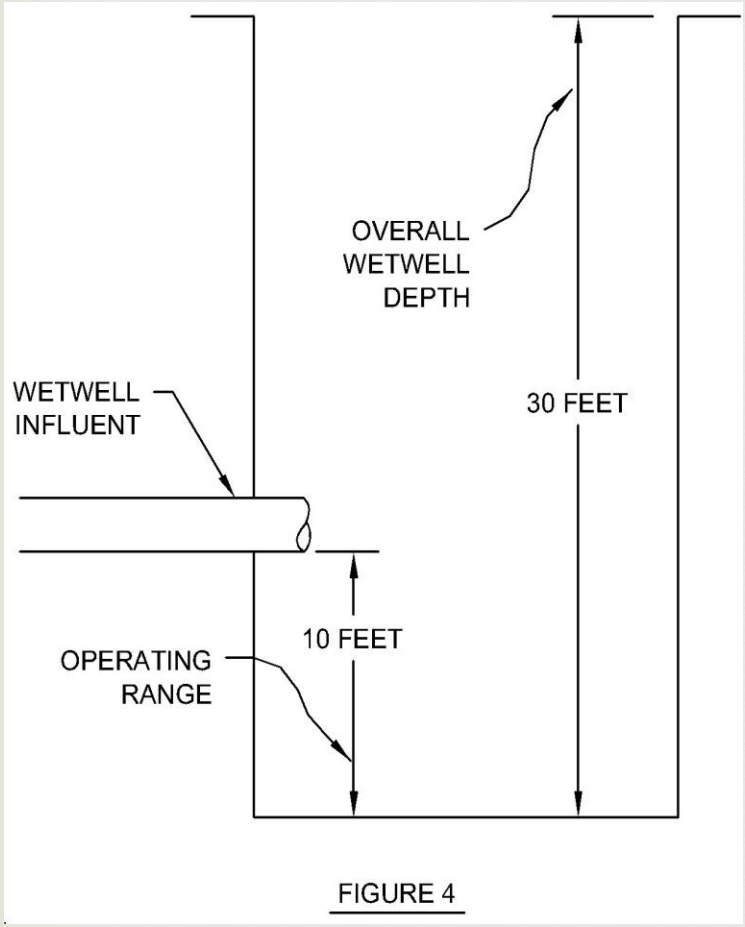


FIGURE 4

- The most common transducers are the 5psi, 10psi, and 15psi transducers.

- 5psi has a range of 0-11.5 feet
- 10psi has a range of 0-23.1 feet
- 15psi has a range of 0-34.6 feet

Sizing a Submersible Transducer

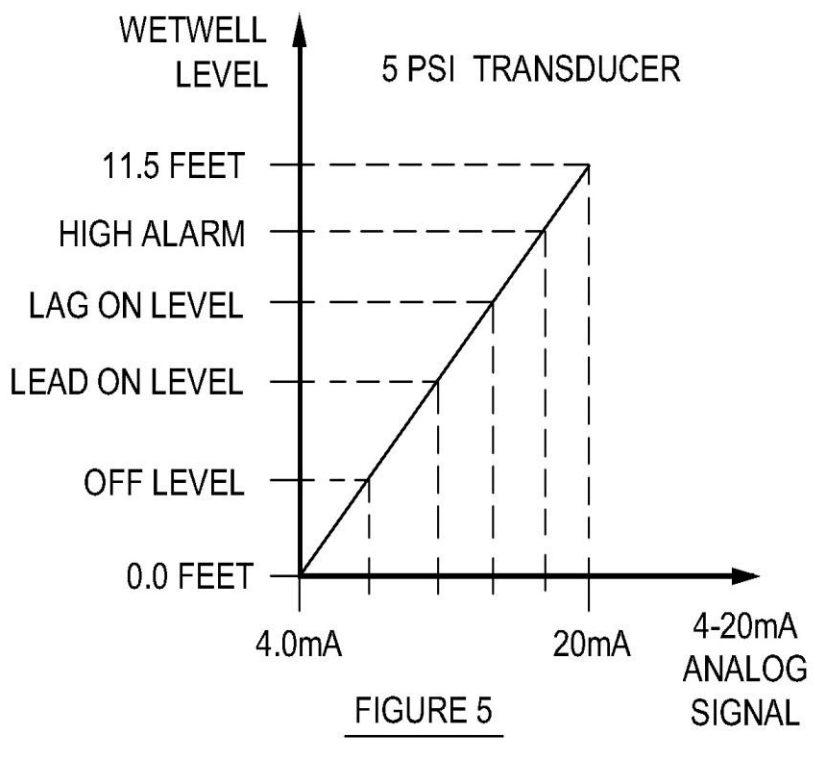


FIGURE 5

- When you select the transducer range to match the operating range of the wetwell, you have the best resolution for control of that application.
- For the figure shown, the entire 4-20mA range is available for lift station control. (Good Resolution!)

Sizing a Submersible Transducer

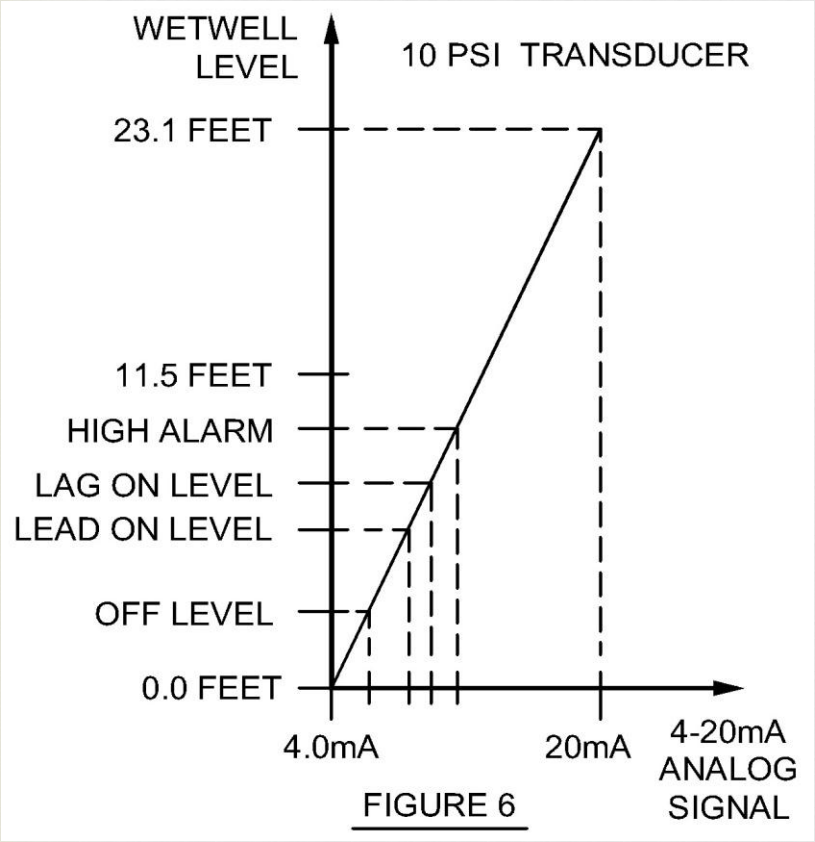


FIGURE 6

- When you select the transducer range that does not match the operating range of the wetwell, you begin to lose resolution for control of the application.
- For the figure shown, a 10psi transducer is used in an application calling for a 5psi transducer.

Sizing a Submersible Transducer

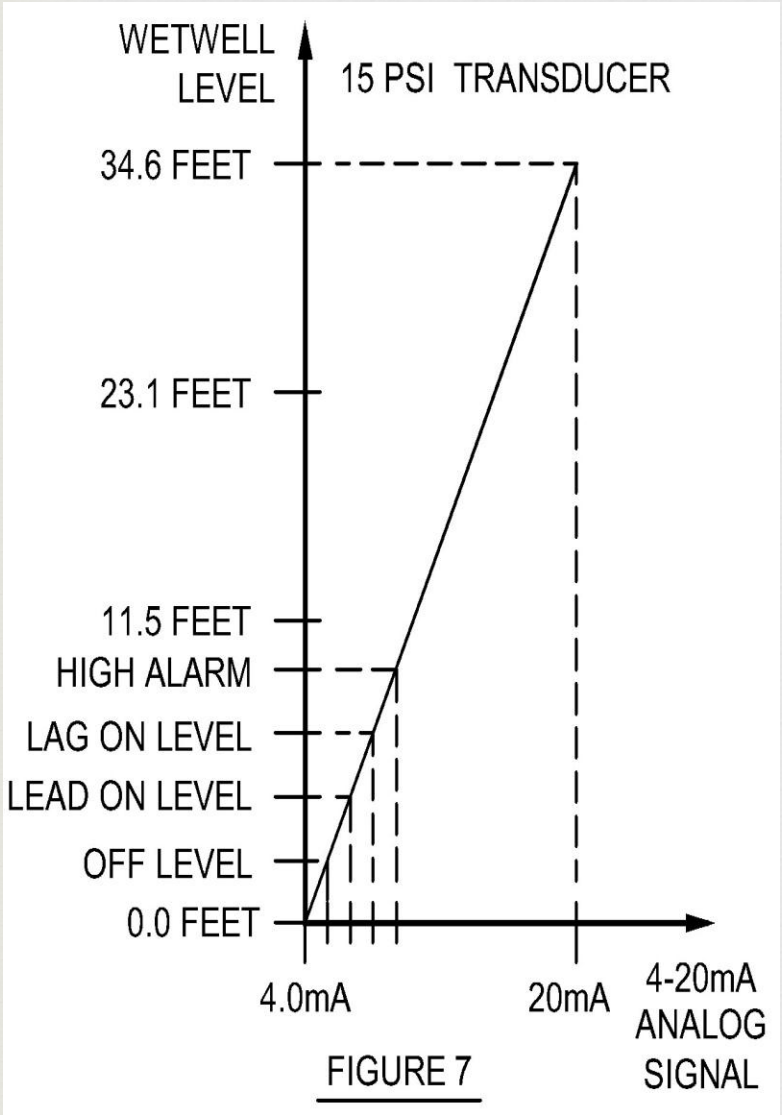


FIGURE 7

- One size does not fit all when it comes to submersible transducers.
- Resolution continues to deteriorate the further the transducer range is from the actual operating range.
- For the figure shown, a 15psi transducer is used in an application calling for a 5psi transducer.

Controls Topic #3

The 4-20mA Current Loop

The 4-20mA Current Loop

- Used to transmit analog data representing various process variables such as level, pressure, flow, temperature, etc.
- Although conceptually simple, the 4-20mA loop can be tricky to troubleshoot.
- Represents a fair % of MPE technical calls.

The 4-20mA Current Loop

- If you have a control system with a 4-20mA level signal, you need the following:
  - A good meter that reads 4-20mA DC
  - A loop calibrator, or adjustable transmitter

Loop Calibrator / Adjustable Transmitter

- Simulates a 4-20mA signal from field devices while testing control equipment
- Used to calibrate equipment having a 4-20mA analog input
- Should be part of everyone's tool box

The 4-20mA Current Loop

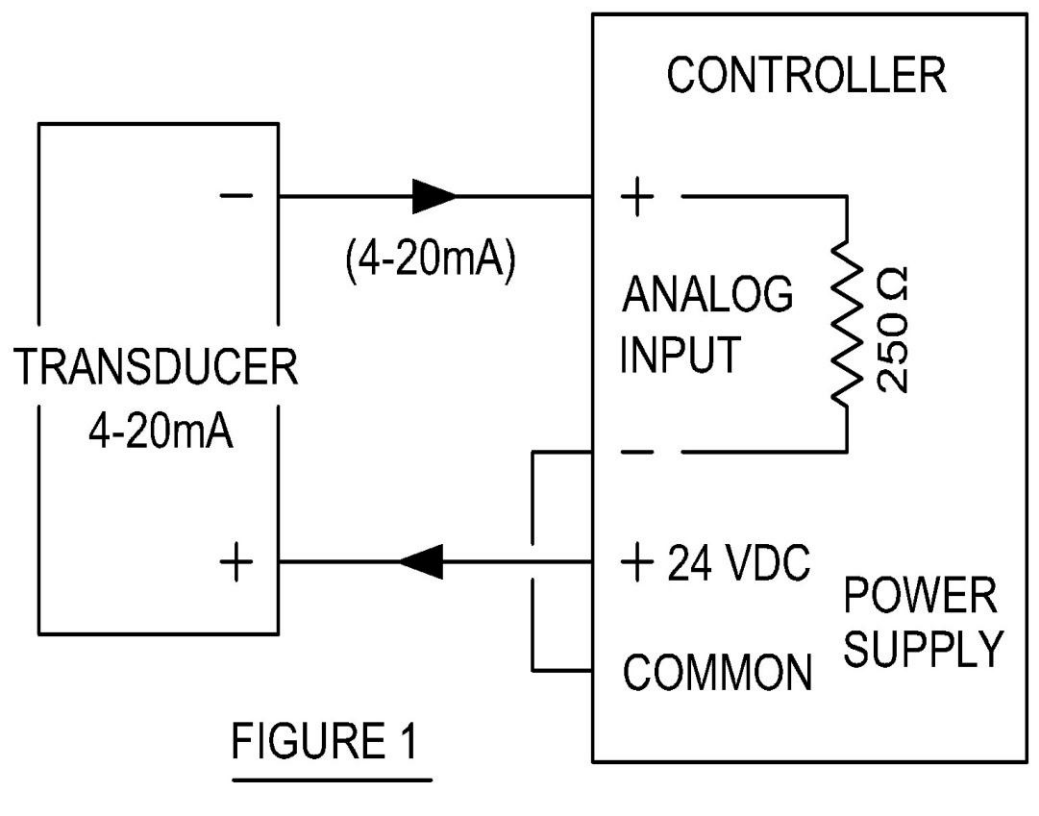


FIGURE 1

- This is a series connected loop, and current flow is in the same direction throughout the loop.
- Controller shown has an internal power supply
- 250Ω represents the Controller input resistance

The 4-20mA Current Loop

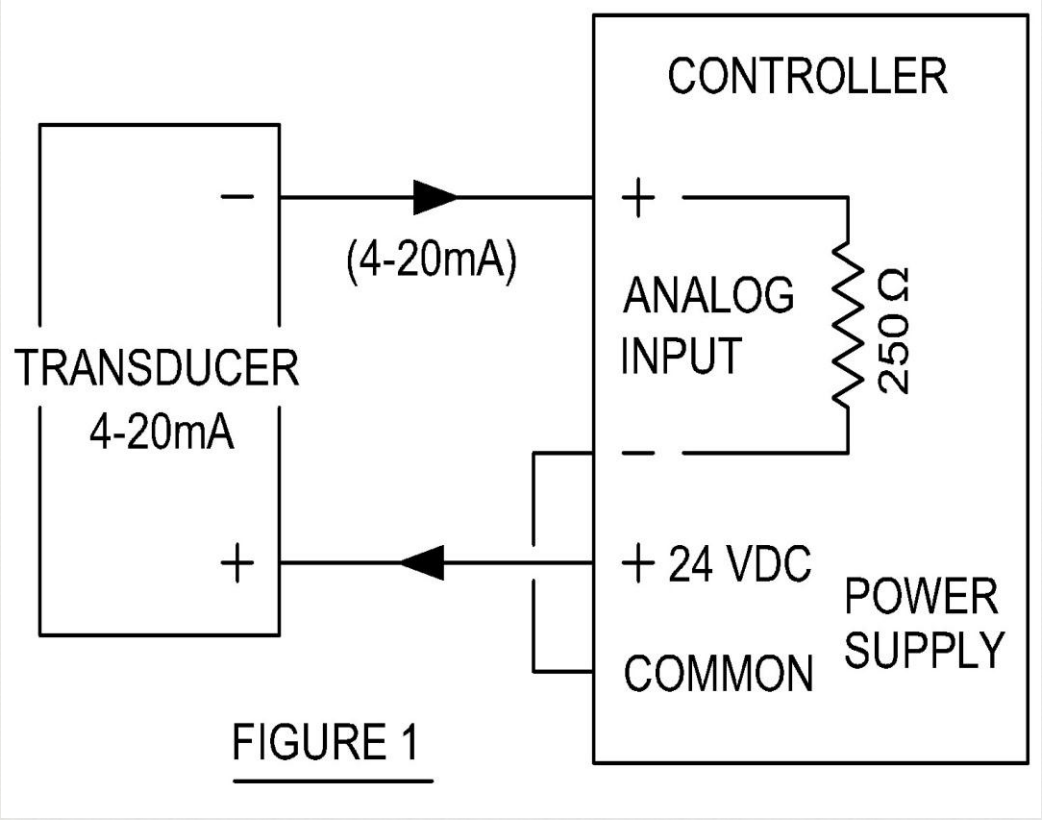


FIGURE 1

- Rule of thumb for connection within the loop:
- Start with connecting the positive lead of the power supply to the positive lead of the transducer.

The 4-20mA Current Loop

- There are two types of instruments used in a current loop:
  - Loop powered instruments are powered by the DC power supply placed within the loop.
  - Non-loop powered devices require a separate voltage source for the instrument to be used in the loop.

A more involved 4-20mA Loop

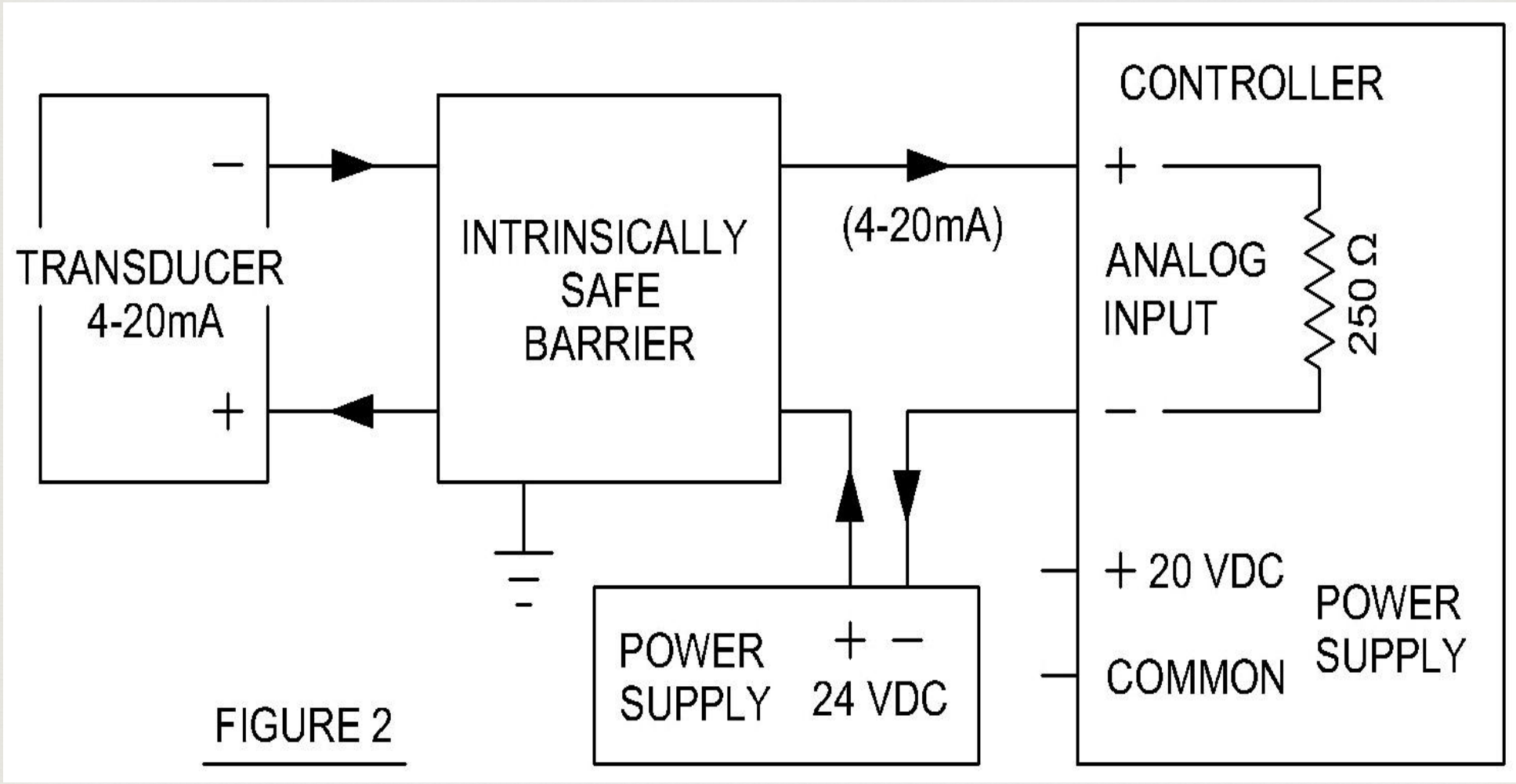


FIGURE 2

The 4-20mA Current Loop

- Care must be taken to ensure that the impedance of the loop instruments, and the loop DC Voltage allows for a full 20mA to flow in the loop.
- A quick check to ensure your loop will operate properly is to add the voltage drop across each device in the loop, and make sure this does not exceed the DC Voltage supply powering the loop.

The 4-20mA Current Loop

- Why is the 4-20mA current loop preferred over voltage control?
- DC voltage control circuits are affected by noise - it adds to the DC voltage and causes error.
- Convenience of looping items together

The 4-20mA Current Loop

- Why is the 4-20mA current loop preferred over voltage control?
- Each loop impedance drops a certain amount of the loop voltage, but the current remains constant. (Only the impedance of the transducer changes to vary the loop current.)

The 4-20mA Current Loop

- Two of the most common problems encountered when designing a 4-20mA loop are:
  - Enough voltage
  - Too much voltage

The 4-20mA Current Loop

- Two of the most common obstacles encountered when working with a 4-20mA loop are:
  - Polarity
  - Unintentional grounding

Controls Topic #4

Isolated vs. Non-Isolated Analog Level Inputs

This gets a little tricky!

Isolated vs Non-Isolated Analog Level Inputs

- Isolation with regard to a controller's analog level input has to do with whether or not the Analog Input (-) common is connected to the Controller's internal power supply common, which is typically connected to control panel ground. (Quite a mouthful!)

Isolated vs Non-Isolated Analog Level Inputs

- An isolated Analog Level Input (-) common will be free from any connection to control panel ground.
- It will also be free from any connection to the common of any other analog loop.

Isolated vs Non-Isolated Analog Level Inputs

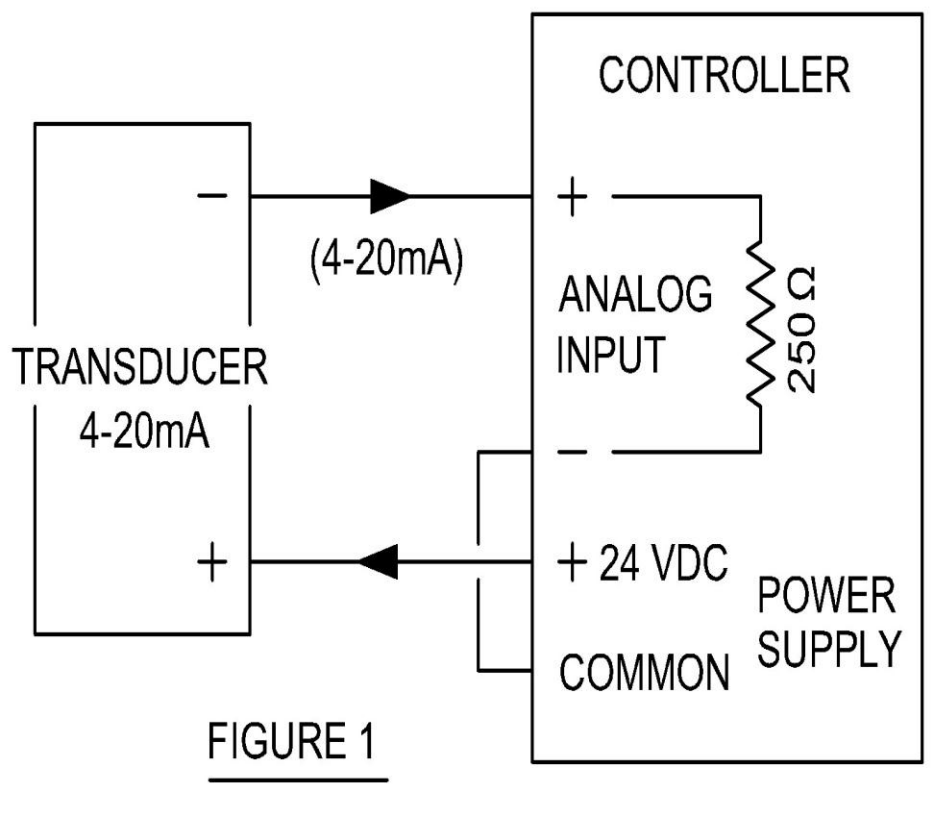


FIGURE 1

- For the majority of analog level input applications, isolation for the level input is not required.
- Here the loop powered transducer has no ground connection, so no isolation is required.

Isolated vs Non-Isolated Analog Inputs

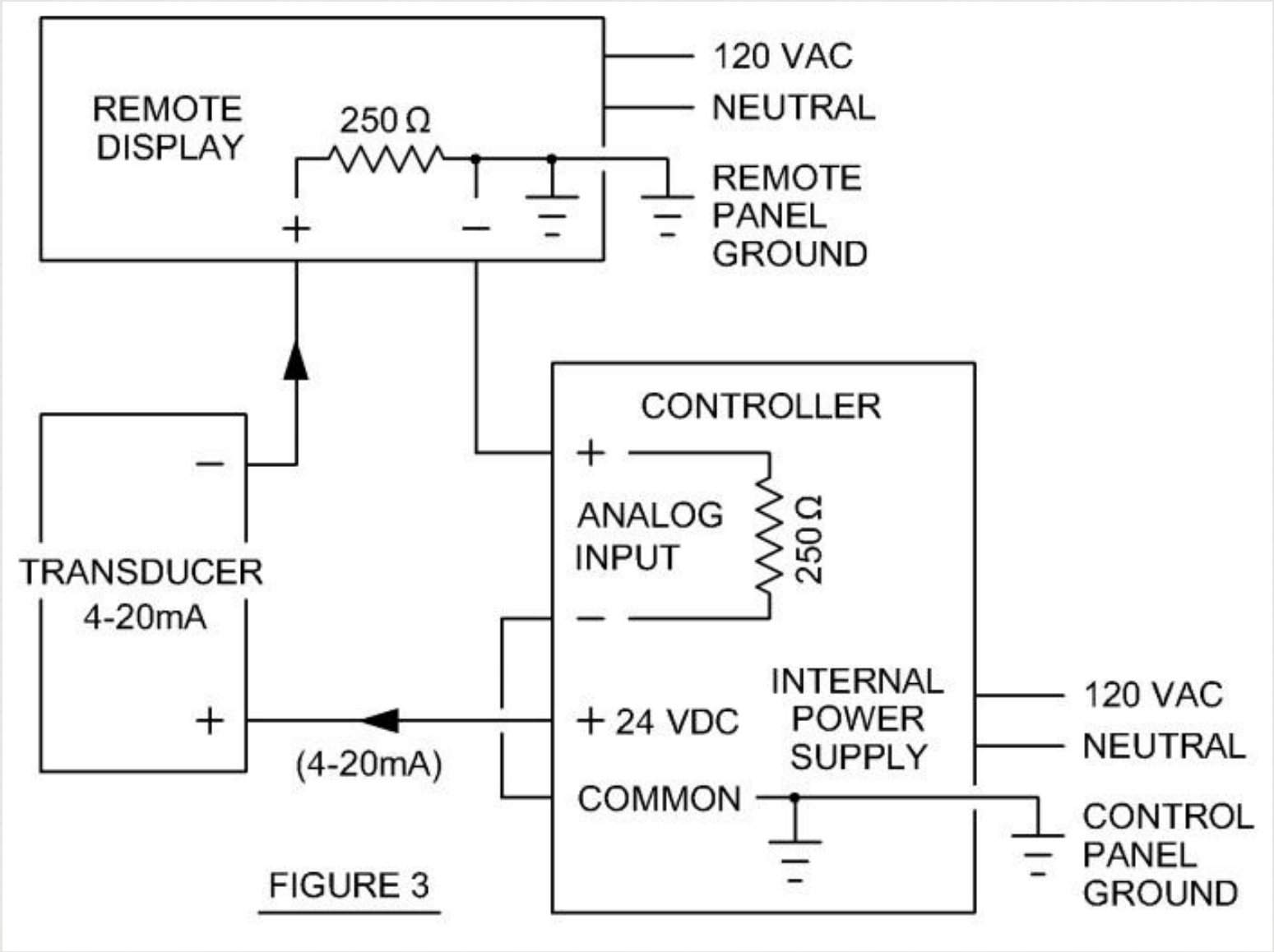


FIGURE 3

Controls Topic #5

Linear Level Control vs. PID Control

Linear Level Control vs PID Control

- There are two types of Level Control:
  - Linear Level Control, also known as Proportional Control
  - PID (Proportional-Integral-Derivative)

Linear Level Control vs. PID Control

- Linear Level Control is used for both constant speed and variable speed applications.
- PID Control is used only in variable speed applications.

Linear Level Control vs. PID Control

- For most lift station control applications, proportional control (Linear Level Control) is sufficient, and desirable for simplicity.
- A typical Linear Level Control application would include an pump-off point, lead pump-on point, lag pump-on point, and the high level point.

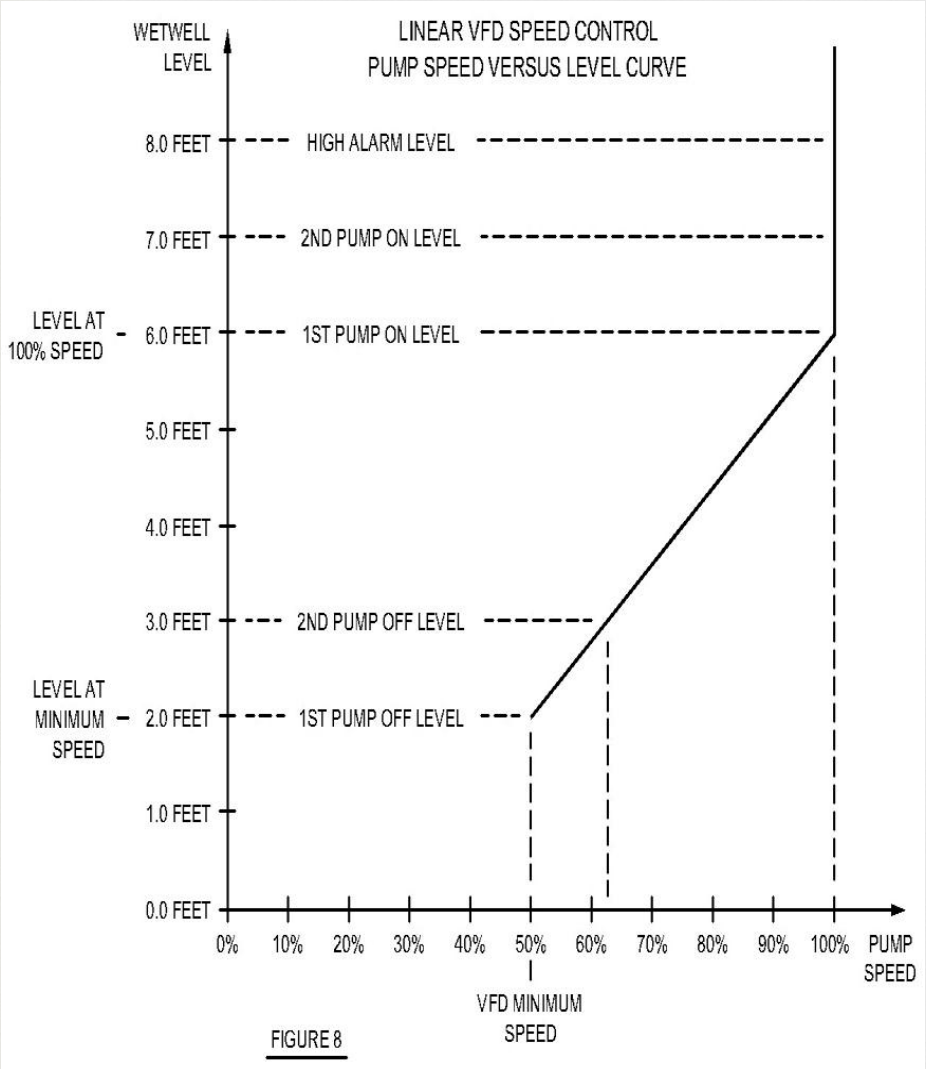
Linear Level Control vs. PID Control

- For Linear Level Control, the relationship between the level in the wetwell, and the control of the pumps is proportional.
- In other words, if the level calls for a pump to run, a pump is called to run until the off point is reached.

Linear Level Control vs. PID Control

- Advantages to Linear Level Control:
  - Simplicity in setup
  - Lower equipment cost
  - No "sludge ring" in the wetwell, as the level does not stay in one place for any length of time.

Linear Level Control vs. PID Control



- Typical VFD setup for Level Control requires three parameters
  - VFD Min Speed
  - Level at Min Speed
  - Level at 100% Speed

Linear Level Control vs. PID Control

- When a VFD Linear Level Control application is set up correctly, the control system will run one or more pumps at some speed between minimum speed and 100% speed, and continually make adjustments to the pump speed as needed to keep up with the flow into the lift station.

Linear Level Control vs. PID Control

- PID Control is also known as set-point control.
- PID Control is used to maintain a setpoint for a process variable such as level, flow, temperature, or pressure.

Linear Level Control vs. PID Control

- As the process variable begins to move away from the setpoint, the Proportional part of the PID Control makes a change to the speed reference that is proportional to the error, or difference, between the setpoint and the process variable being controlled.

Linear Level Control vs. PID Control

- The Integral part of the PID loop determines how fast the speed reference is being changed to move the process variable back to the desired setpoint.

Linear Level Control vs. PID Control

- The Derivative part of the PID loop slows the rate of change of the speed reference signal to reduce the "overshoot" effect of the Integral part of the PID control.

Linear Level Control vs. PID Control

- PID Control requires that the control system be "tuned", or adjusted for the best performance of the control system.
- PID Control is only necessary where tight (accurate) control is required for the application.

Linear Level Control vs. PID Control

- PID examples:
  - Controlling flow into a treatment plant
  - A booster system for maintaining building water pressure

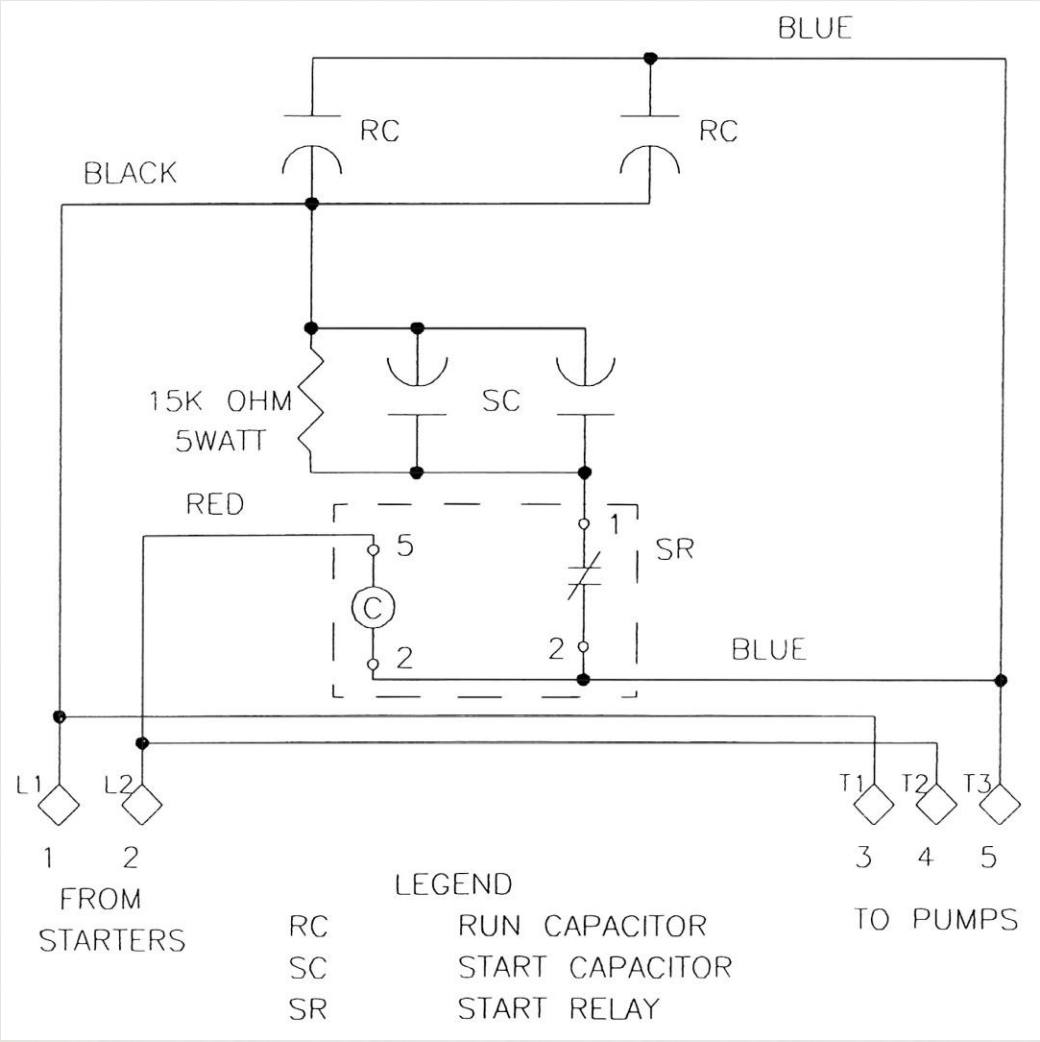
Controls Topic #6

VFD's vs. Single Phase Modules (For Single Phase to Three Phase Conversion)

VFD's vs Single Phase Modules

We don't see the application using Single Phase Modules for phase conversion as much as in the past, but the concept here is good for explaining the function of Start and Run Capacitors.

VFD's vs Single Phase Modules



- L1 connected to T1
- L2 connected to T2
- L1 also goes through Start Cap SC, and Slave Relay SR, to get to T3
- After SR opens, the current flow for T3 comes through the Run Cap, RC

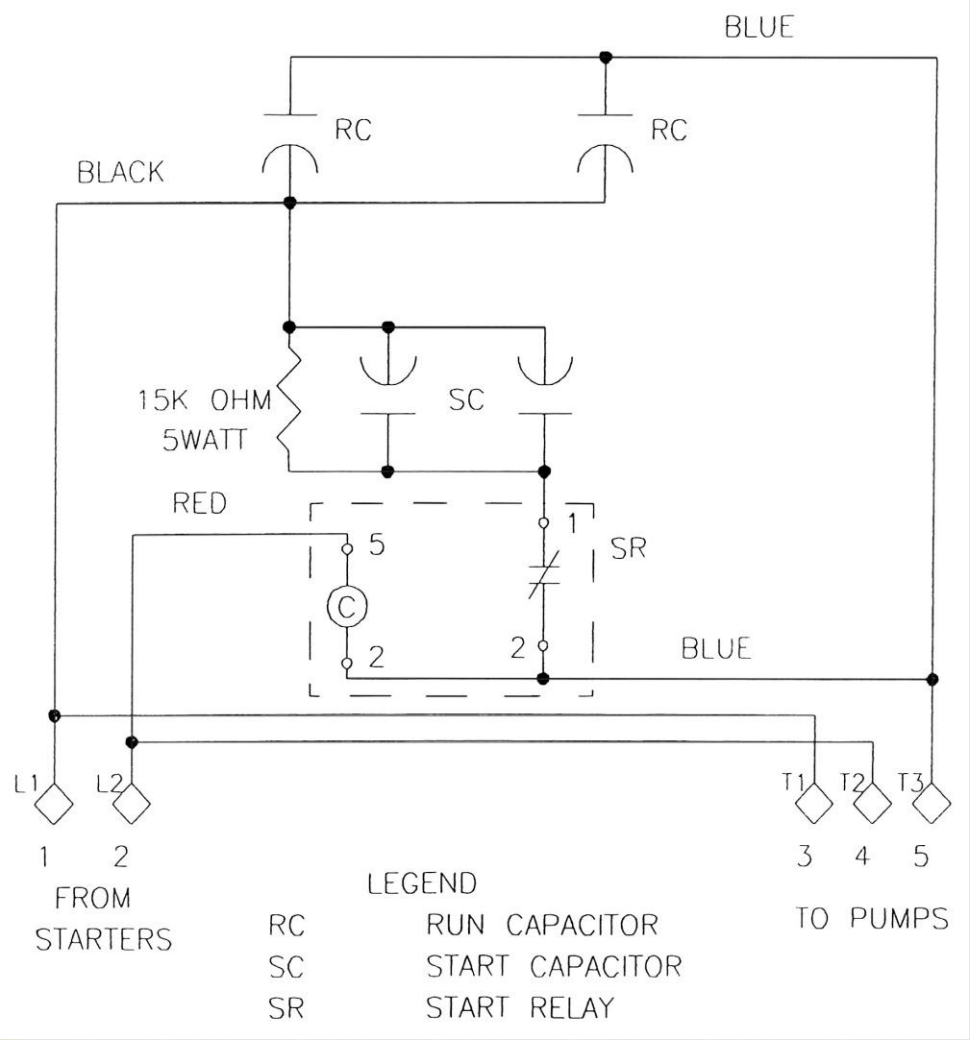
VFD's vs. Single Phase Modules

- How do you tell the Start Cap from the Run Cap?
- Start Cap has greater Capacitance value than Run Cap.
- $X_C = 1/[2(\Pi)(f)(C)]$
- A larger value of "C" gives a lower value of Impedance, X_C

Bonus Thought

- Line Reactors are Inductive
- The Impedance, X_L, increases as the frequency increases.
- $X_L = 2(\Pi)(f)(L)$
- Harmonics, which are multiples of the Base frequency 60Hz, are effectively blocked by the increase in Impedance, X_L.

VFD's vs Single Phase Modules



- The Start Caps, SC, have a lower impedance so current flows through this path first, giving the motor a "Starting boost"
- Once the motor is running, current flow is changed through the Run Caps, RC

VFD's vs. Single Phase Modules

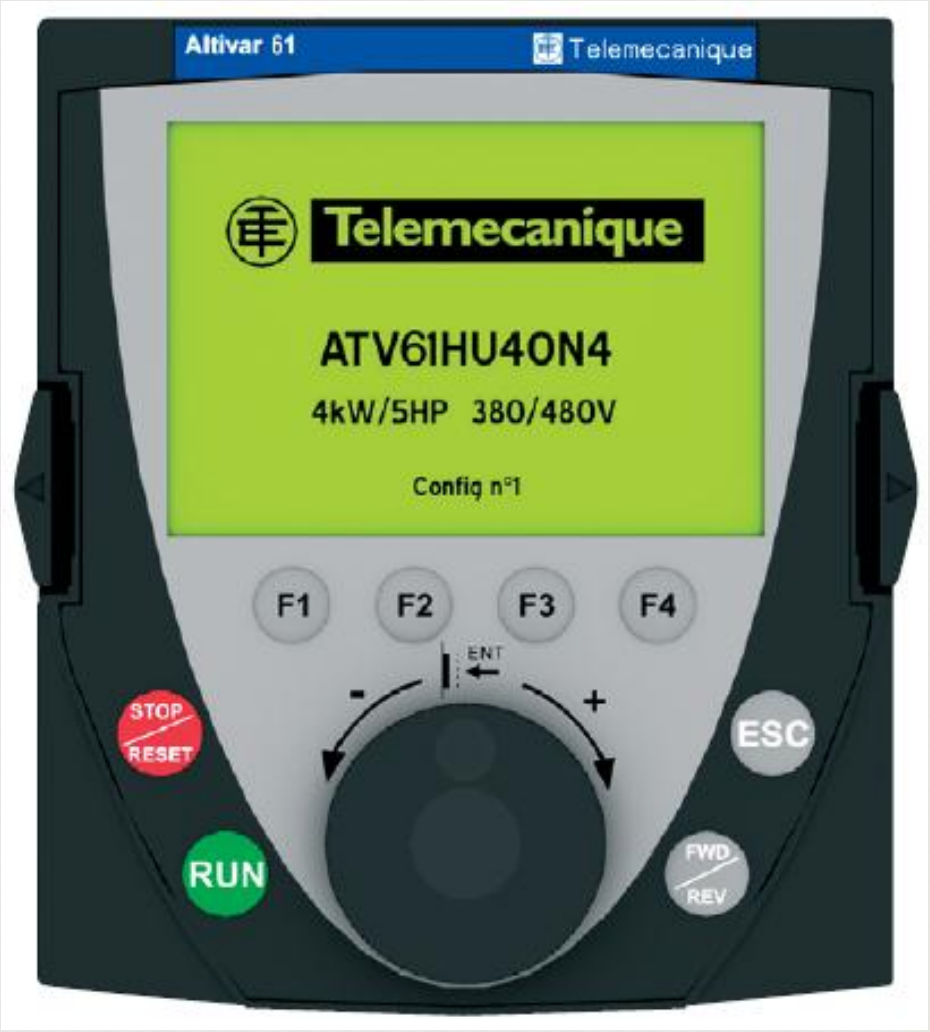
- For many years now, there has been a movement away from using the Single Phase Modules to using Variable Frequency Drives for conversion from single-phase to three-phase voltage.
- Why is this?

VFD's vs. Single Phase Modules

- Problems with SPM's:
  - 3-Phase voltage not balanced
  - Low starting torque
  - Nuisance tripping if start relay goes bad
  - Start and Run caps need to be described in the panel builder's UL file/procedure

VFD's vs Single Phase Modules

- VFD's can be used as a "Phase Converter" by de-rating for Single Phase application
- Output is balanced, true Three-Phase
- 100% Torque available
- Proven technology



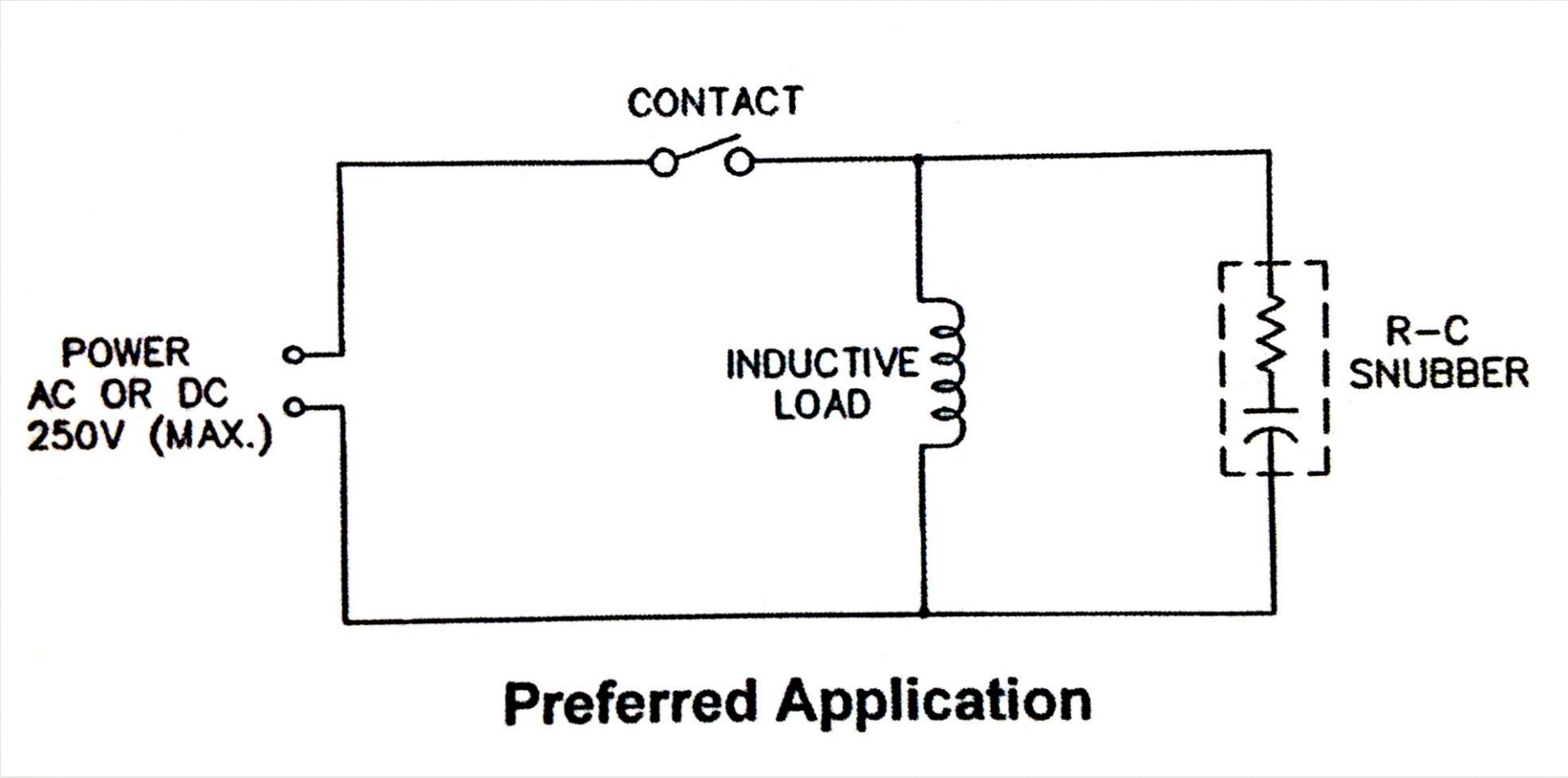
Controls Topic #7

What is a Snubber, and how does it work?

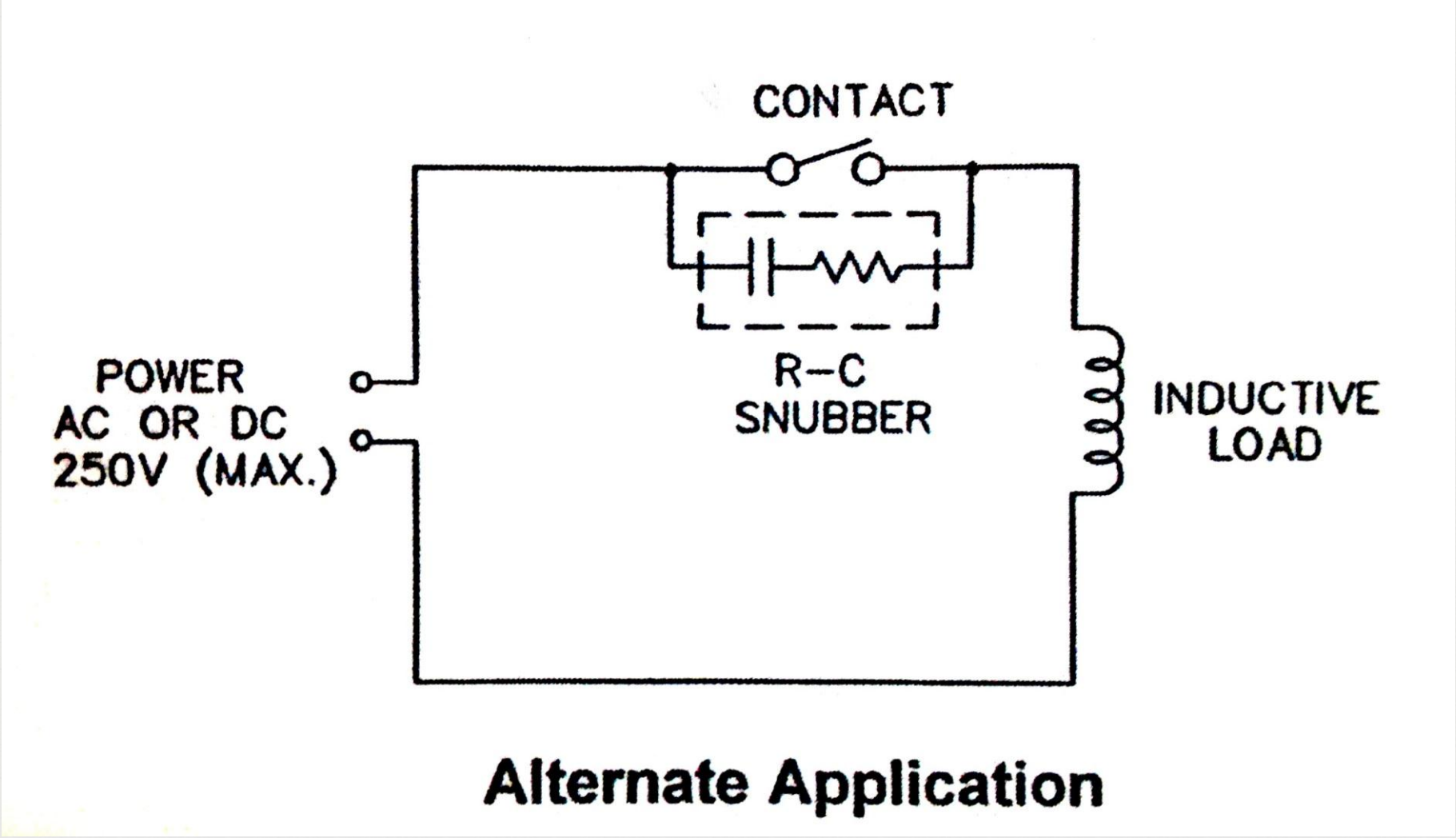
What is a Snubber ?

A Snubber is a series connected Resistor and Capacitor, placed across an inductive load, to reduce a voltage transient.

What does a Snubber look like?



What does a Snubber look like?



Transient Explanation

- When the voltage to the coil of a motor starter or a relay is removed quickly, a large voltage spike can develop across the coil as the field collapses.
- The voltage spike is of very short duration, but may be quite high in voltage.

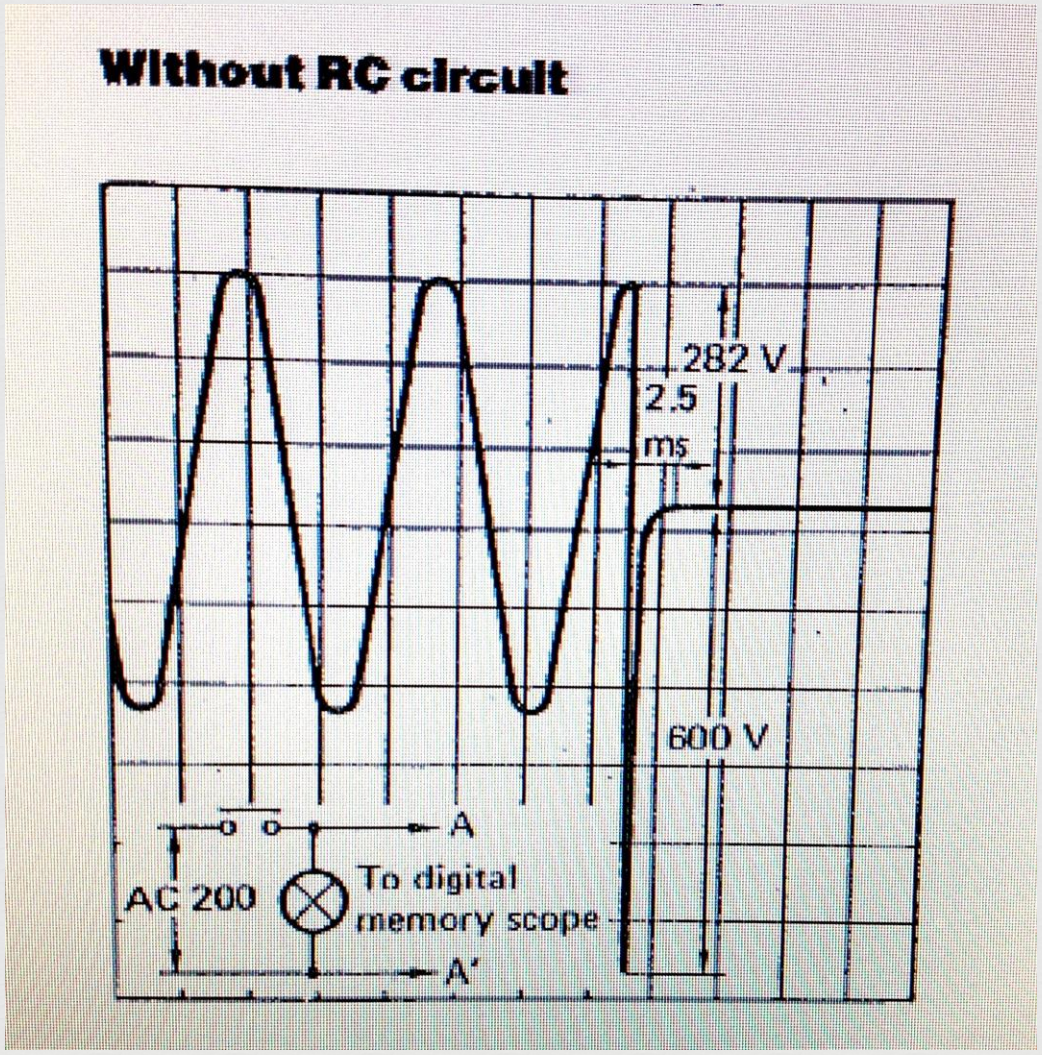
Transient Explanation

- The formula for this phenomena is:

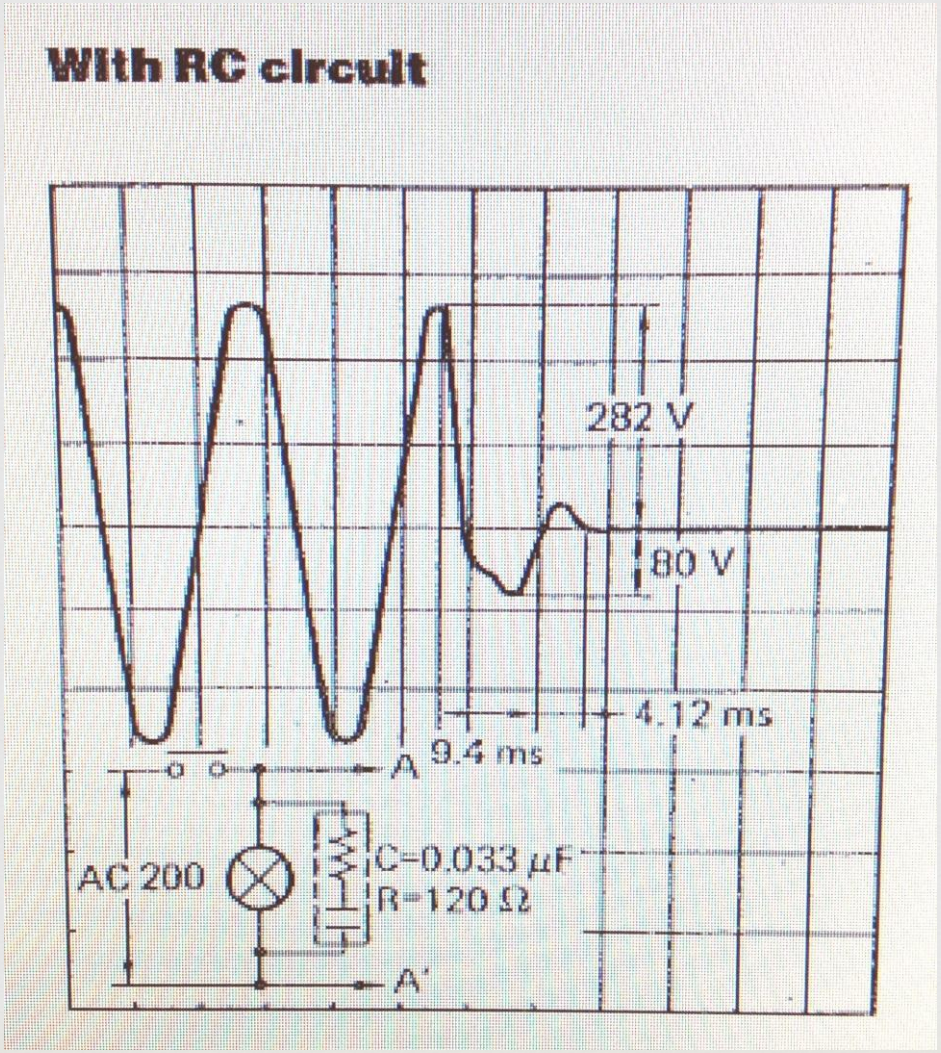
$$V = L \, di/dt, \text{ where:}$$

- V = Transient Voltage developed across the coil
- L = Inductance of the coil
- di/dt = Change in current with respect to time

What the transient looks like with no Snubber across the coil



What the transient looks like with a Snubber across the coil



Snubber Explanation

- A Snubber, consisting of a resistor and capacitor in series, changes the slope of the rise time of the transient.

- The resistor and capacitor form a filter that absorbs the very fast rise time, and shifts the slope of the transient so that it becomes a non-issue.

Selecting a Snubber

- Values for R and C are chosen so that they equal or come close to the rise time of the transient.

- (R * C) = time constant
- Set time constant equal to rise time measurement from oscilloscope.

Selecting a Snubber

- A resistor value of 100 Ohms is fairly common, which leaves us to solve for the value of the capacitor.
- In 120VAC circuits, a rise time of 10uS is fairly common.
- You don't have to be exact – if you're close, you will achieve the desired result of removing the transient.

Rule of Thumb

- It would be good design practice to put a Snubber across the coils of size three and size four motor starters.

- Several companies offer a multitude of Snubbers which have leads long enough to be tucked away in your control panel wiring duct work.

Question Time!

Thanks for listening to me!