Cause and Effect of External Electrical Interferences (Noise) on Microprocessor-Based Equipment

Instruction Notice

Objective: Provide the reader with an understanding of the types of external electrical influences which are present in the operating environment and the possible effect on microprocessor-based process measurement and control equipment. Also provide recommendations to minimize the effect.

General

Electrical disturbances caused by lightning, motors and motor driven devices, relays, solenoids, and communication equipment often introduce electrical noise in power lines, transmission lines, and site grounds. The successful operation of any microprocessor-based device depends, in part, on the precautions taken to minimize the effect of these disturbances especially in areas where older analog electronic or pneumatic instruments are being replaced.

In the most simple terms microprocessors receive, accumulate, process, and send data as a string of pulses and spaces. If a pulse occurs where a space should be or if a pulse is canceled from the string, data will be processed incorrectly. The end result depends on when the data error occurs in the string and how it is processed. Some of the fault conditions which could occur are:

- minor, randomly intermittent, deviation of measured value
- minor bumps in output value
- large deviations in process and/or output value
- a shut down command
- an undefined condition where the device could:
    - erase the stored program
    - fail to a defined set of conditions
    - blank its display
    - lock itself to a set of conditions and not allow any change
    - change a single line of configuration
    - be any combination of the above

While conditions described might be caused by a defective component(s), most often these conditions are caused by external electrical interferences. i.e., noise.

As a comparison, consider pneumatic instrumentation. The power source is a supply gas. This supply gas, usually compressed air, must be generally free of water vapor, compressor oil, and airborne particles. If the supply gas contains contaminants or if the particle size is too large nozzles, orifices, and transmission lines will become partially or totally plugged. The result will be erratic operation or instrument failure. Guidelines and recommended practices for instrument air quality have been defined (reference: ISA; RP7.3 and RP7.7). Filter systems, sometimes very elaborate, are installed at the inlet and/or outlet of the compressor. In addition, simple filter-regulators should be installed at the instrument to effectively provide a clean, well regulated, source of power to the instrument.

Todays microprocessor-based devices require the same type of considerations; i.e., relatively noise free well regulated sources of AC power.

What is a well regulated power source?

A reasonable definition is; the primary source of supply voltage, AC or DC, should not vary more than the supplier's published limits. Operating specifications supplied by the manufacturer might define their limits as; 117 V ± 10% or 234V ± 10% , 50/60 Hz, or, 24 V dc ± 10%. As long as the primary voltage remains within the defined limits it is regulated well enough.

What happens if the power source is not regulated to these limits?

If the power source voltage exceeds the manufacturer's published limits, either high or low, a device (usually an integrated circuit type voltage regulator) in the power supply circuit will sense this condition and initiate a shutdown sequence. Once the voltage returns to an acceptable limit the instrument **should** initiate a restart sequence and reapply power to the instrument. Failure messages might appear as defined in the manufacturer's operating instructions. Manual operations may be required to return the instrument to an "on-line" condition.

Caution: If an overvoltage condition should occur it is possible that the actual peak voltage value might be high enough to cause permanent damage.

What should be done to insure that the power source remains within the recommended operating limits?

Ideally, each microprocessor-based device should be provided with a dedicated power source. This will effectively provide continuous load to the power source. Large load changes caused by motor driven devices starting and stopping should be removed from this circuit.

Where this approach is not feasible due to space available or cost per device an acceptable alternative is to install constant voltage, isolation transformers in the branch circuit where the microprocessor-based device (or devices) is installed. The transformer will provide a constant output for a varying input and the isolation feature will assist in the reduction of line noise.

Installation and wiring practices defined by the National Fire Protection Agency (NFPA) in their National Electrical Code (NEC) handbook or State agency amendments to this code should be strictly observed.

Caution: Some forms of constant voltage systems such as battery backup systems using inverter circuitry to produce AC like outputs may produce an output waveform which is not a pure sine wave. The output waveform may not be compatible with the installed device. Check with the supplier of the microprocessor-based device before selecting the final choice of power regulation system.

What is noise?

Specifically referenced to this discussion; noise is the unwanted external interferences superimposed on the power source, signal lines, and ground. Often called "transients" or "voltage spikes" this form of noise is infinitely variable in terms of amplitude, frequency, and duration.

Common sources of this type of noise are:

- loose or poor quality connections [esp. power connections]
- arc welding equipment
- switches operating inductive loads
- relays, solenoids and other coil operated devices
- high current conductors – electric heater circuits
- fluorescent or neon lamps
- motors and motor driven devices
- switch mode devices – SCRs, thyristors
- lightning
- electrostatic discharges

Microprocessor-based devices are more susceptible to these forms of noise than "analog" devices because of the lower working voltages and much faster switching speeds used in the circuit design. Typically the microprocessor logic voltage is switched between 0 Vdc and 5 Vdc. The circuit supply voltage is usually ± 15 Vdc. As a comparison "analog" instrument supply voltages are often 24 Vdc or higher and seldom require 0 Vdc as a reference voltage for signal conversion.

The manufacturer of the microprocessor-based device designs the power and signal circuits to reject as much of these unwanted interferences as possible. The success of the design is defined in the product specifications as noise rejection and usually is referenced as Common mode and Normal mode rejection.

- common-mode noise is any voltage difference that exists between each terminal connection and a common point.
- normal-mode noise is any voltage difference that exists between the terminal connections; either the power source line to neutral or process signal input.

The ability to reject each condition is usually expressed in decibels (db). The decibel is a dimensionless measure of power ratios as a defined relationship to the logarithmic scale.

As a guide for product selection; COMMON-MODE specifications equal to or greater than 80 db is good. Anything above 100 db is better. For NORMAL-MODE 30 db is good, 60 db and higher is better.

Why worry about external noise if the manufacturer has designed-in safeguards?

The intent of this discussion is not to suggest that every microprocessor-based device will fail because of external noise. The user of these devices should recognize the potential risk, understand the cause of the fault condition if it occurs, and apply the appropriate corrective actions or preventative measures as necessary.

Lightning, for example, is recognized as a destructive noise source. In areas where lightning strikes are frequent the user will install additional equipment such as lightning arrestors and surge protectors which are specifically designed to provide a reasonable degree of protection to the installed equipment.

In older facilities, especially where microprocessor-based devices are replacing pneumatic or "analog" electronic equipment, the risk of potential noise induced failures increases significantly. Miniature lightning strikes caused by arcing are common. Pitted relay contacts, worn switches and motor brushes, dirty motor commutators, loose or poor quality connections all cause the electrical energy to arc the gap caused by wear and age. The effect of this type of noise may be no less destructive than lightning. In addition, panel grounds and even primary ground paths may have become corroded or disconnected long ago. Signal wiring may be exposed or lay in cable trays (or conduit) with power wires. All are sources of potential risk beyond the manufacturer's ability to filter or reject the combined effect of the energy and frequency levels which could exist.

What should be done to minimize the effect of external noise?

Preventative measures can be applied at the time of installation or, applied as corrective action once a noise induced fault condition has been determined to exist. The choice is the exclusive responsibility of the end user.

Suggested preventative measures:

Primary power circuit distribution system:

- Ideally, each microprocessor-based device should be provided with an independent dedicated power source. Where this approach is not feasible due to space available or cost per device an acceptable alternative is to install constant voltage, isolation transformers in the branch circuit where the microprocessor-based device (or devices) is (or are) installed.

- In addition to the above, install a combination TRANSIENT SURGE SUPPRESSOR AND NOISE FILTER in the instrument side of the power distribution system. The combination device suppresses transients and effectively reduces other noise forms such as electromagnetic (EMI) and radio frequency (RFI) interferences. Cost of these type devices is generally less than $110 and they can be connected to multiple units which further reduces overall cost.

Input signals

- Twisted wire pairs are essential. The wire type should be stranded not solid. The largest single conductor wire gauge defined by the manufacturer is best and the more twists per foot the better. A 2-inch lay (6 twists per foot) should be the minimum used.

- In addition to the above the signal wires should be physically isolated from all power conductors (separate conduit, cable race, etc.)

- If shielded wire is used. Shields should be terminated as defined by the equipment manufacturer or in accordance with local regulations.

  CAUTION:
  1. Never terminate a shield at both ends. One end should always be left "floating."
  2. Thermocouple shields should be terminated at the process measurement end. Most thermocouples are constructed where the sensor is electrically equivalent to the process connection (grounded junction)

Equipment grounding:

- Grounding practices defined by the National Fire Protection Agency (NFPA) in their National Electrical Code (NEC) handbook or State agency amendments to this code should be strictly observed.

- Existing ground conductors and ground paths should be periodically inspected and tested to insure continuity and compliance with current code requirements.

- For best noise reduction performance the microprocessor-based device's ground terminal should be connected to a nearby grounded large metal structure, using the shortest length wire possible. If a three-wire cordset is used to power the microprocessor-based device through a receptacle, the ground wire is generally too long and too noisy to be a good ground.

References:

National Electrical Code: 1990 edition

National Fire Protection Assoc.
Batterymarch Park, Quincy, MA 02269

Guide for the installation of electrical equipment to minimize electrical noise inputs to controllers from external sources: IEEE STD. 518-1982

Institute of Electronic and Electrical Engineers
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Electromagnetic compatibility for industrial-process measurement and control equipment: IEC publication 801 (series)

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Quality Standard for Instrument Air : ISA - S7.3
Recommended Practice for Producing Instrument Air : ISA - RP7.7

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