Relay Scheme Design Using Microprocessor Relays

A report to the
System Protection Subcommittee of the
Power System Relay Committee of
the IEEE Power & Energy Society

Prepared by working group C16
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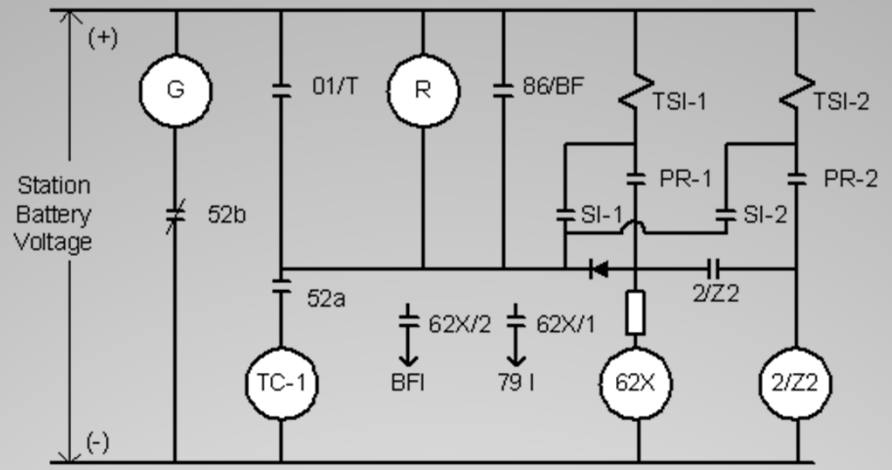
This paper is intended to supplement to the existing 1999 relay trip circuit design paper to address the use microprocessor relays

- Modern relays are changing the way substations are engineered
- They enable many functions to be carried out through one piece of hardware
- This flexibility and compactness is sometimes the cause of increasing levels of complexity



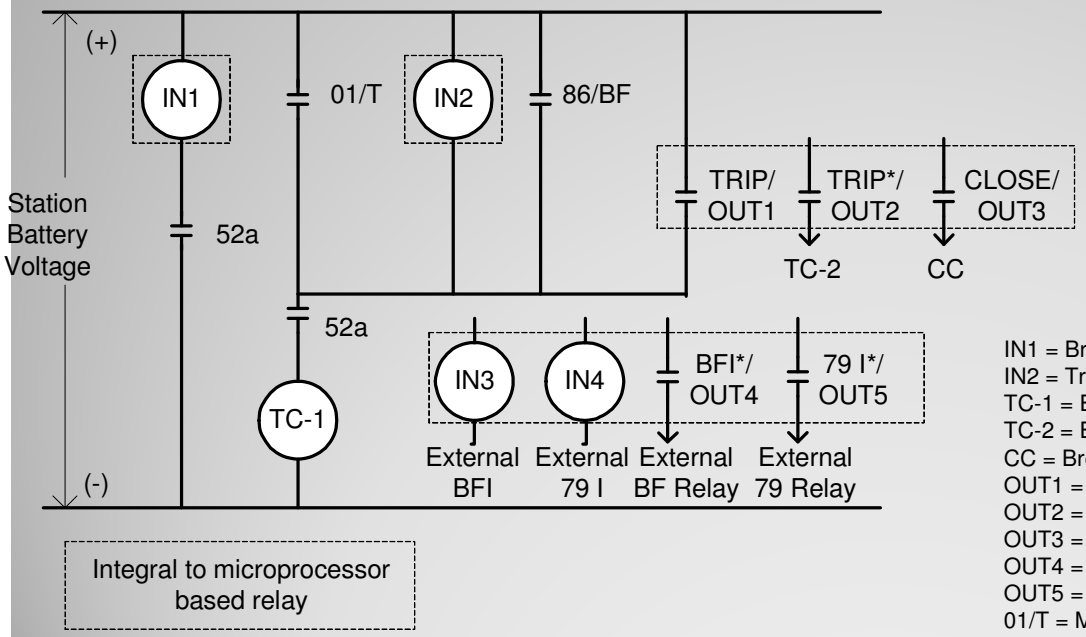
G = Green breaker status light
R = Red breaker status light
TC-1 = Breaker trip coil 1
2/Z2 = Zone 2 timer and associated output contact
62X = Auxiliary timer
PR = Protective relay trip contact
SI = Seal-in contact
TSI = Trip seal-in auxiliary relay coil
01/T = Manual control switch trip contact
86/BF = Breaker failure lockout contact
52a = Breaker auxiliary form "a" contact
52b = Breaker auxiliary form "b" contact
BFI = Breaker Failure initiate
79 I = Auto reclose initiate

Typical Trip circuit using Electromechanical relays

Considerations When Using Microprocessor Relays

Trip circuits

- Typical breaker trip circuit using microprocessor relay



IN1 = Breaker status input
IN2 = Trip circuit monitor input (optional)
TC-1 = Breaker trip coil 1
TC-2 = Breaker trip coil 2
CC = Breaker close coil
OUT1 = Protective relay trip contact
OUT2 = Protective relay trip contact (* if second trip coil present)
OUT3 = Protective relay close contact (manual or autoreclosing)
OUT4 = Protective relay breaker fail initiate contact (*if external BF relay present)
OUT5 = Protective relay reclose initiate output (*if external 79 relay present)
01/T = Manual control switch trip contact
52a = Breaker auxiliary form “a” contact
86/BF = Breaker failure lockout contact
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General Scheme Design

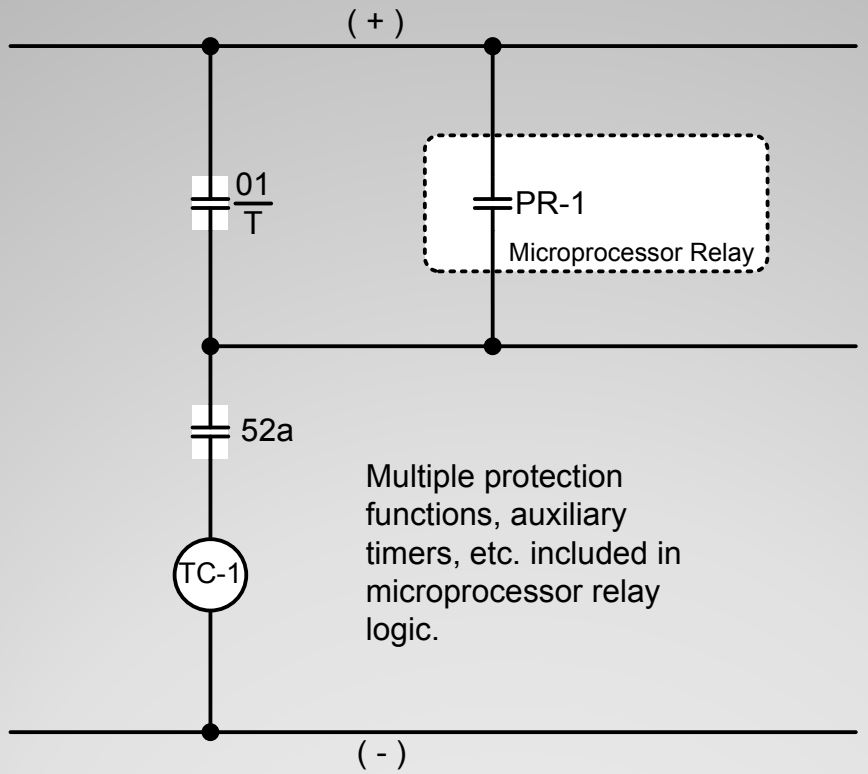
Trip Circuit

- Microprocessor relays can simplify trip circuit design
- Multiple isolated outputs on a single relay can be used to trip multiple breakers

Integration, Separation, and Redundancy

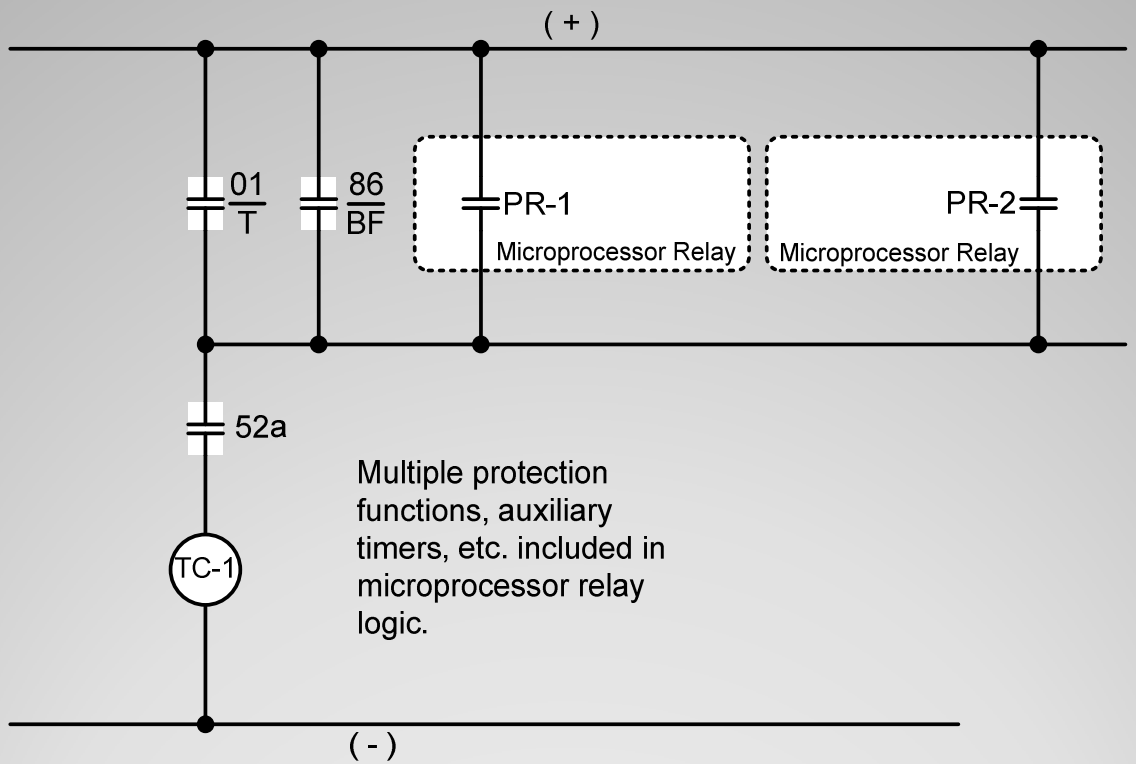
- Combining functions into one relay can reduce size of equipment, reduce wiring, and lower cost
- However, it can lead to problems such as measurement or programming errors effecting multiple protection functions
- Thought must be given to creating redundant systems which can function despite total failure of a relay
  - Ex: Duplicate functions using relay from different manufacturer

Direct Tripping



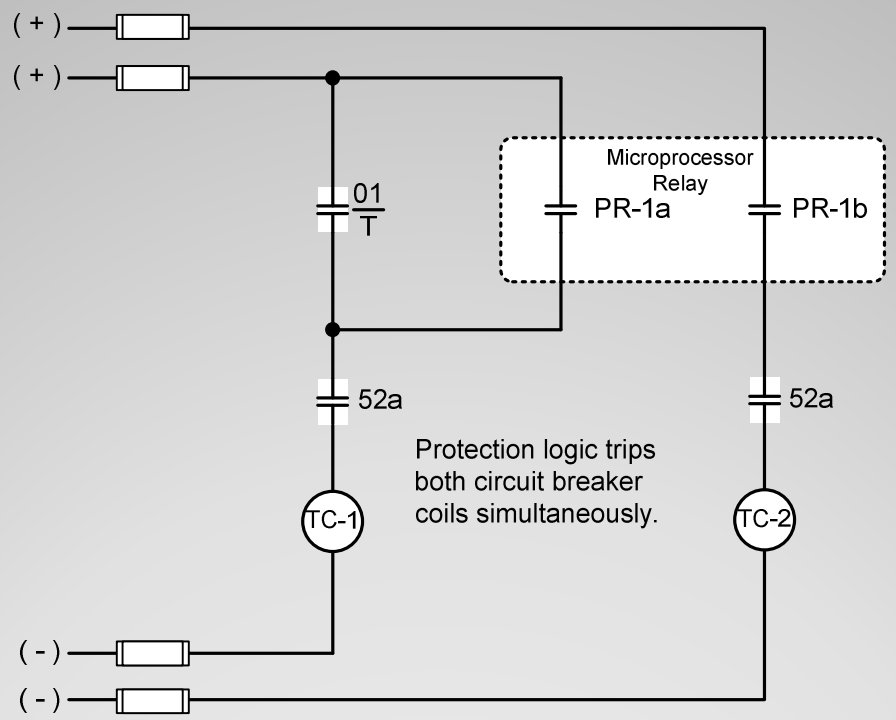
52a	Breaker auxiliary form “a” contact
52b	Breaker auxiliary form “b” contact
TC-1	Trip Coil 1
01/T	Breaker control handle Trip
PR	Protective relay trip contact

Dual Relay Tripping



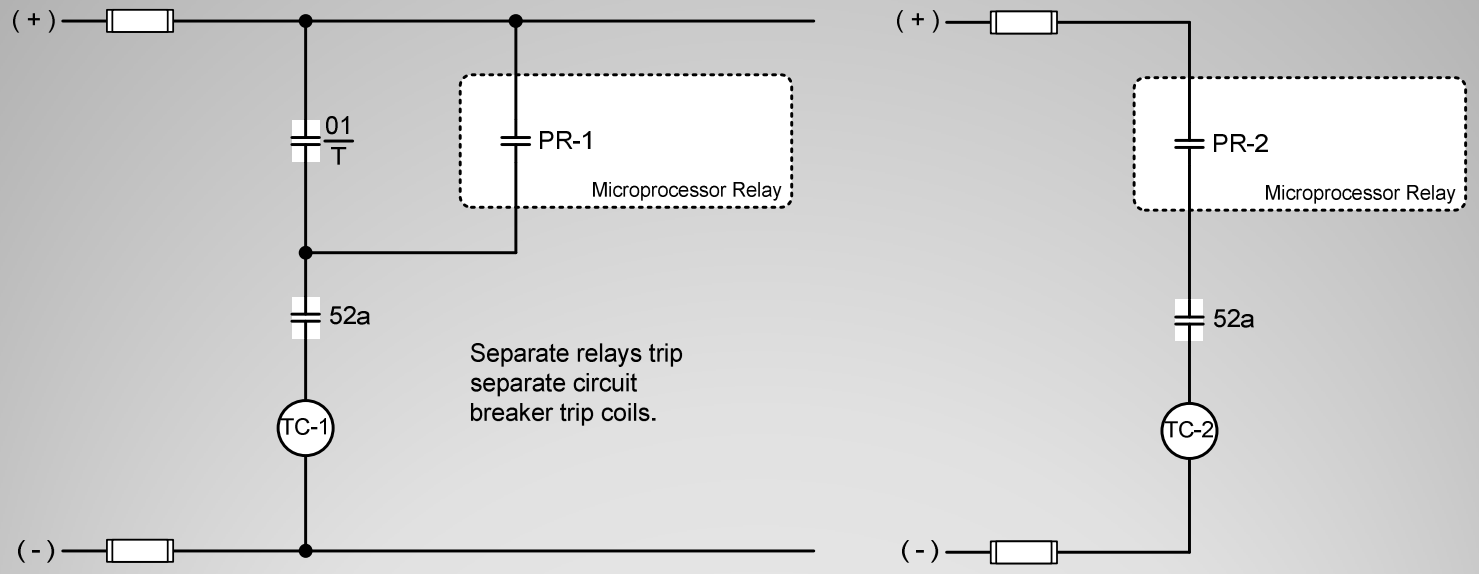
52a	Breaker auxiliary form “a” contact
52b	Breaker auxiliary form “b” contact
TC-1	Trip Coil 1
01/T	Breaker control handle Trip
PR	Protective relay trip contact
86/BF	Remote breaker failure trip via lockout relay

Dual Trip Coils with One Relay



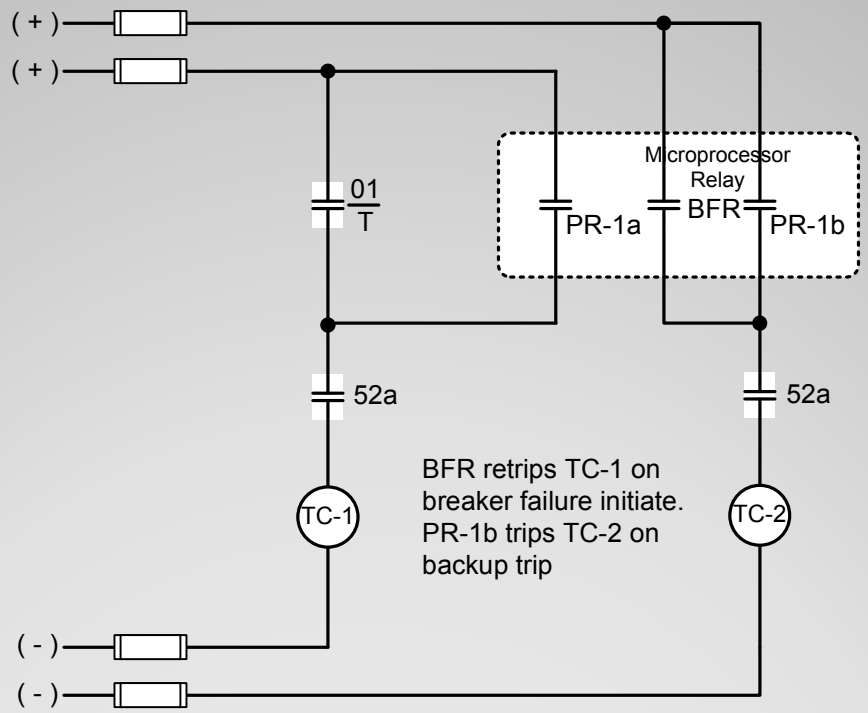
52a	Breaker auxiliary form “a” contact
TC-1	Trip Coil 1
TC-2	Trip Coil 2
01/T	Breaker control handle Trip
PR	Protective relay trip contact

Dual Trip Coils with Two Relays



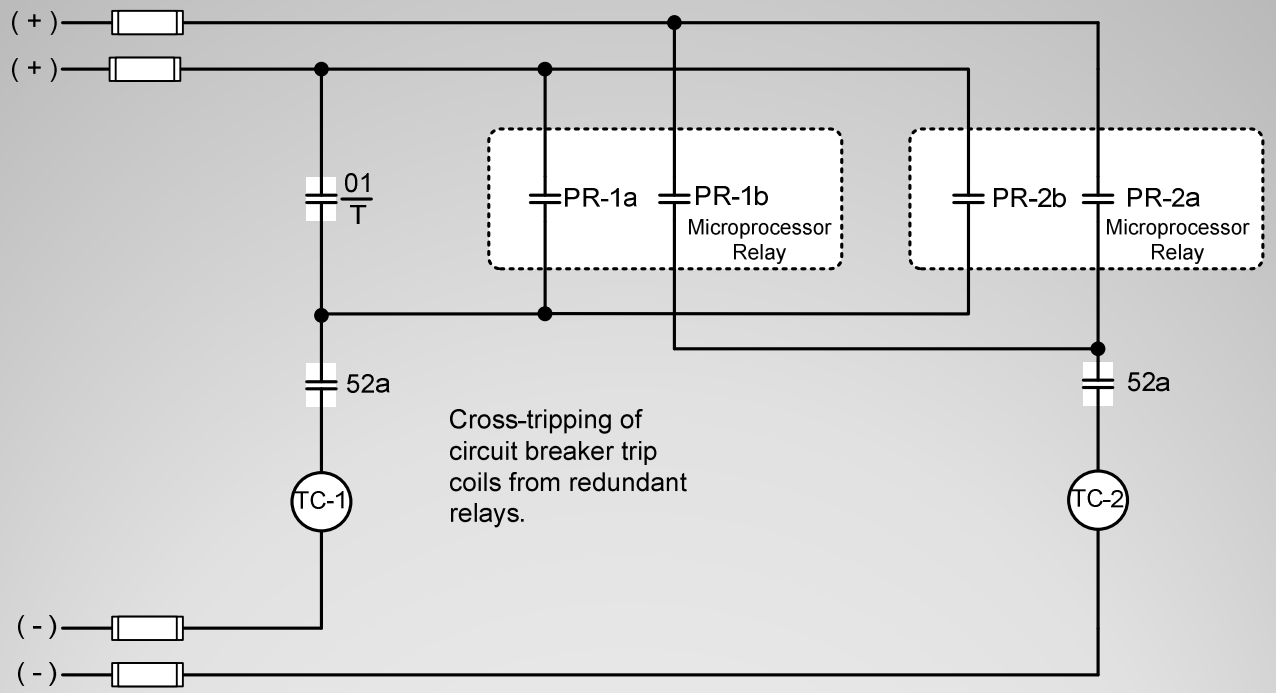
52a	Breaker auxiliary form “a” contact
52b	Breaker auxiliary form “b” contact
TC-1	Trip Coil 1
TC-2	Trip Coil 2
01/T	Breaker control handle Trip
PR	Protective relay trip contact

Dual Trip Coils with Breaker Re-trip



52a	Breaker auxiliary form “a” contact
TC-1	Trip Coil 1
TC-2	Trip Coil 2
01/T	Breaker control handle Trip
PR	Protective relay trip contact
PR-1b	Protective relay backup trip contact
BFR	Breaker failure retrip contact

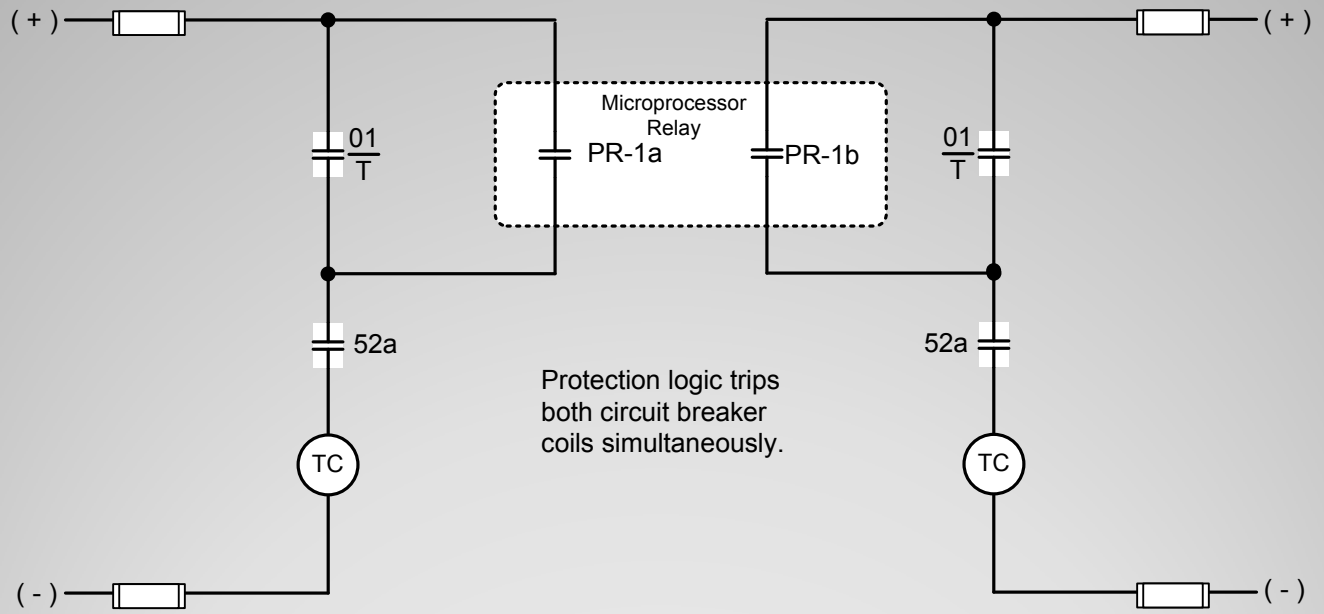
Dual Trip Coils, Relay Cross-Tripping



52a	Breaker auxiliary form “a” contact
52b	Breaker auxiliary form “b” contact
TC-1	Trip Coil 1
TC-2	Trip Coil 2
PR	Protective relay trip contacts

Probably most common today

Dual Breaker Scheme



52a	Breaker auxiliary form “a” contact
TC	Trip Coil
01/T	Breaker control handle Trip
PR	Protective relay trip contact

There are a few problems

Circuit Contacts

- One leading cause of failure is burned and failed output contacts due to inductive DC current
- Must ensure circuit contact being used is properly rated for all possible signals
- Often can assess by calculating L/R rating:

$$\text{L/R rating} = \frac{\text{Load Inductance}}{\text{Load Resistance} + \text{Cable Resistance to Load}}$$

- Relay manufacturers are developing ways to mitigate burnout

Circuit Contacts (cont.)

- Speed of relay contacts must be considered
- Typical closing time is 3 to 8 milliseconds

- Choosing incorrect contacts can lead to leakage or sneak currents
- Extend Seal-in time and/or add arc suppression

PRO

- Low CT burden

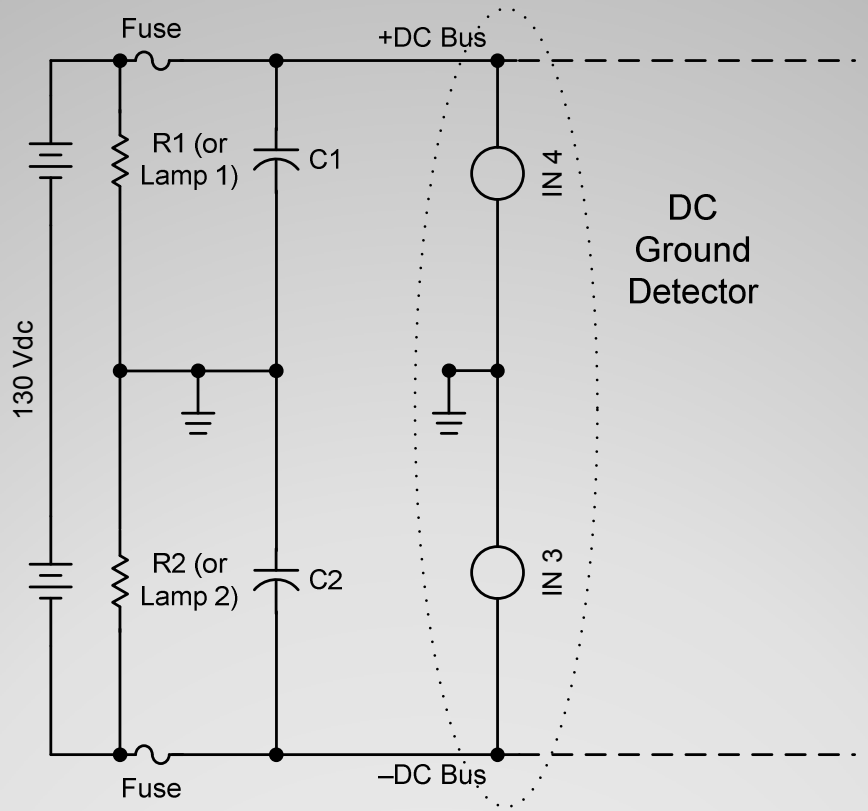
CON
Battery Creep

- Upgrading stations typically leads to increased continuous DC system loads
- Once adequate DC supply systems may need to be revisited

Sneak Currents

- Sneak currents are unintended design flaws that can result in serious consequences
- With increased complexity, sneak currents are more likely
- With Microprocessors, the sneak circuits have often moved inside
- Systematic testing and inspection is most common way to prevent
- Many sneak conditions are located through trial and error over time in the field

Battery System Grounding

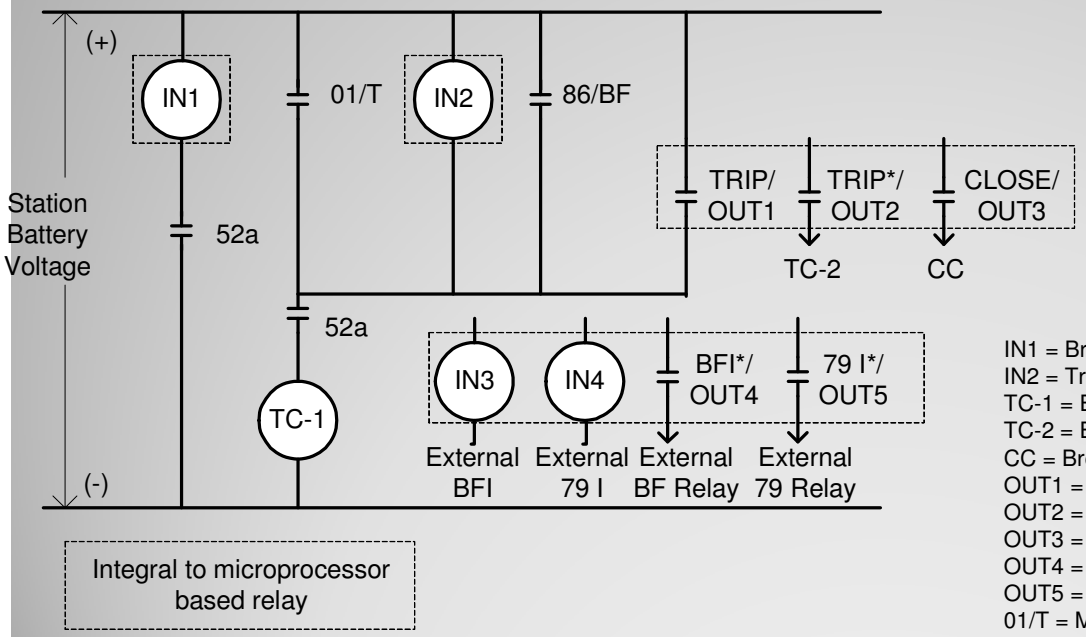


- Can use spare input contacts on relay to monitor grounding conditions of DC system

It’s Not All Bad
there are a few new perks

Trip Circuit Monitoring

- Typical breaker trip circuit using microprocessor relay



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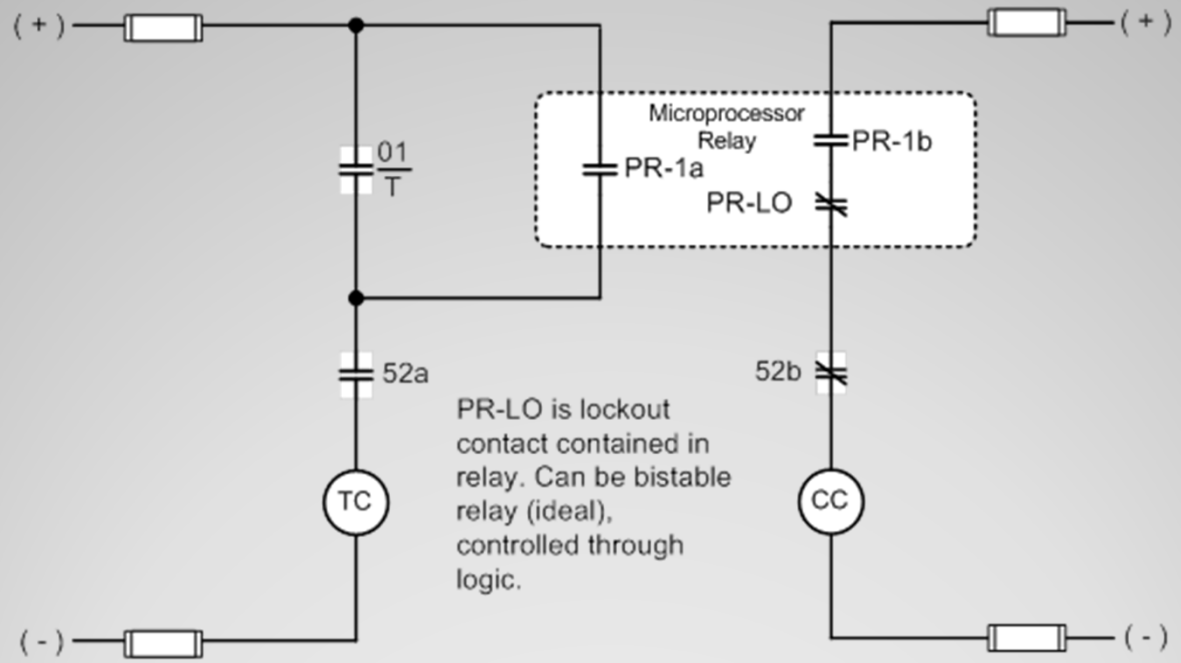
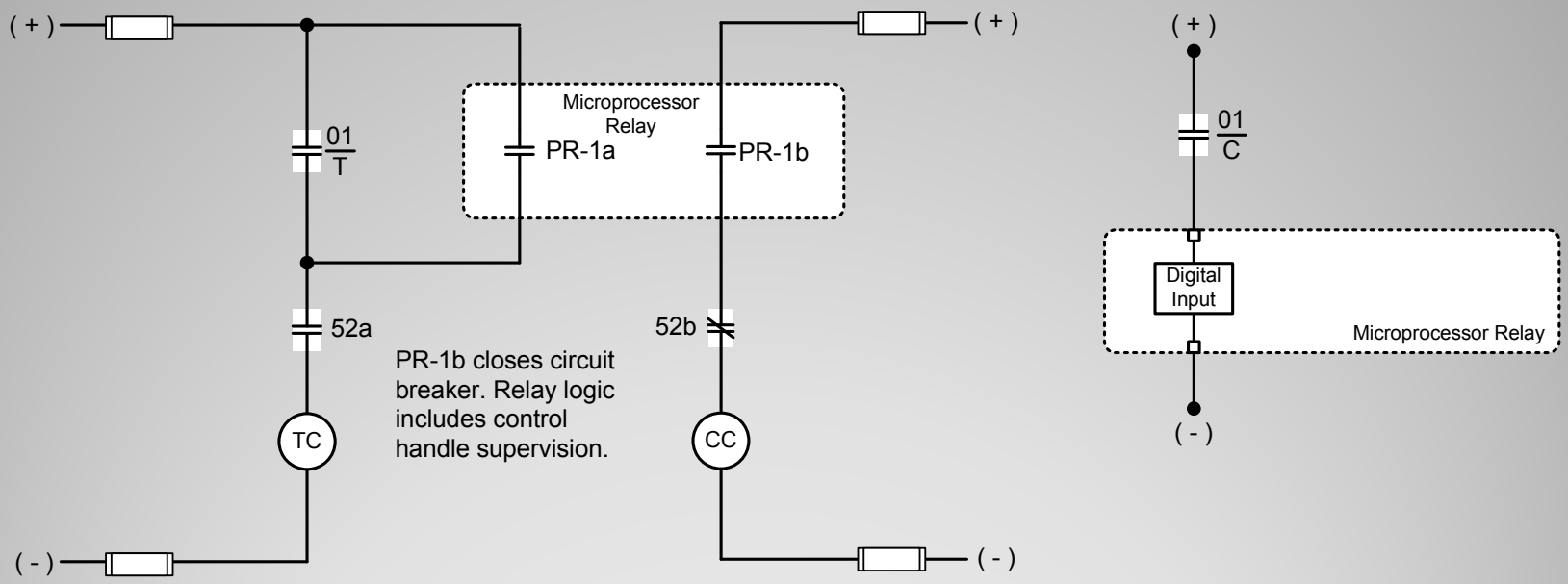
Lockout Function



52a	Breaker auxiliary form “a” contact
TC	Trip Coil
CC	Close Coil
01/T	Breaker control handle Trip
PR	Protective relay trip or close contact
PR-LO	Protective relay lockout contact

Breaker Control Switch



52a	Breaker auxiliary form “a” contact
TC	Trip Coil
CC	Close Coil
01/T	Breaker control handle Trip
01/C	Breaker control handle Close
PR	Protective relay trip contact

SCADA Functions

SCADA Control

- An RTU or other gateway is used to issue open/close commands to circuit breakers, motor-operated switches, and other devices remotely
- Microprocessor relays can act as I/O hardware to implement commands

SCADA Circuit Breaker Control

- CB control implemented using "select-before-operate" concept
- This is intended to prevent any other device from issuing untimely commands to the breaker with unintended results

SCADA Metering and Monitoring

- Microprocessors can greatly simplify monitoring and metering of stations through digital communication through the gateway
- SCADA data collection can be distributed to the microprocessor relays
- These functions used to require an independent electromechanical unit for each

Maintainability and Testing

Multifunction Relay Testing Considerations

- Testing occurs at many stages: acceptance, commission, and as scheduled
- Desire method to conduct tests without changing any relay settings since this could introduce unintended errors
- Some designs may allow for spare contacts which can be used for testing
- Built-in recording functions can be used to determine if appropriate response to test occurred

A couple of additional issues

Test Switches

- Approach on test switches can vary widely
- Test switches may become more rare with microprocessor units since removing all the functions of a single relay at once may be unacceptable
- Test switches enable a relay to be isolated for hot change out

Test Switches part 2

- Testing relays has become more complicated since each relay may be programmed completely differently
- Test switches enable more isolation for testing to prevent inadvertant trips (ie breaker fail outputs)
- Consistent design methods are needed to decrease complexity

Logic Performance Considerations

- Loss of power or network connection can dramatically effect output from relay logic
- Consideration must be given for the default state given either condition
- Volatile memory will reset whereas non-volatile memory will maintain the previous value

Questions?