COMPUTER RELAYS

Hardware and Software
Hardware

1. CPU module
2. Data acquisition unit DAU
3. Power supply unit
4. Bus board

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Hardware

• Analog Processing
• Sampling and A/D Conversion
• Digital Signal Processing
• I/O interface
• User Interface
• Self Checking Techniques
• Technology
• Board Designs
Relay Hardware

Analog Sampling and A/D Conversion

Analog Processing

Analog Processing

Analog Processing

Sampling and A/D Conversion

Digital Signal Processing

I/O Interface

I/O Interface

Input V and I

Output signals (trip, close)

Input V and I

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Analog Processing

- Galvanic Isolation and Scaling
- Low-Pass Filtering
Scaling and Galvanic Isolation

• Auxiliary CT
Auxiliary Transformers
Sampling Theory

\[ f(x) \]

\[ (f * c_w)(x) \]

\[ f(x) \]

\[ (f * c_w)(x) \]

\[ f_c = B < W/2 \]

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Low-Pass Filtering

- Antialiasing filter

- Ideal antialiasing filter – solid line
- Approximate realizable characteristic – dotted line
Filter characteristics

- Cutoff frequency
- Time response
- Phase shift
- Attenuation rate
- Frequency characteristics
Filters – freq. characteristics

Frequency Response (dB)

-60 -50 -40 -30 -20 -10 0

0.1 1 10

6th Order RC
7th Order Butterworth
5th Order Chebyshev
6th Order Bessel
Filters — time response
Passive Filters - realization

- Second order passive filter

![Circuit Diagram]

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Active Filters - realization

- Second order Butterworth filter & Chebyshev filter
Sampling and A/D Conversion

- Sampling of Analog Inputs
- Multiplexing*
- Analog Gain Scaling
- A/D Conversion
Sampling

- Sample and Hold Amplifier
- Scanning
- Synchronous Sampling
Sample and Hold Amplifier

- holds the analogue value steady for a short time while the A/D converter performs conversion
Scanning

- One sample and hold amplifier + one A/D converter
Synchronous sampling

- One S/H amplifier per channel + one A/D converter per channel
Synchronous sampling

- One S/H amplifier per channel + one A/D converter
Analog Gain Scaling

- Gain Scaling Requirement
- Programmable Gain

Gain code

\[
\frac{V_{OUT}}{V_{IN}} = \frac{4096}{\text{CODE}}
\]

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A/D Converter

- Resolution (number of bits)
- Conversion Speed
- Input Range
- Data Interface
- Cost
Resolution

- Phase Currents have large dynamic range (fault currents could be very large)
- Resolution - 12 bits minimum
  - 16 bits recommended
Sampling frequency

Sampling frequencies used in distance computer relays

- 16 samples per cycle → 960Hz (60Hz system) 800 Hz (50Hz system)
- 32 samples per cycle → 1920Hz (60Hz system) 1600 Hz (50Hz system)
- 64 samples per cycle → 3840Hz (60Hz system) 3200 Hz (50Hz system)

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Sampling frequency - example

Sampling requirements Example 1

60Hz system $\Rightarrow$ $T = \frac{1}{f} = 16.6\text{ms}$

16 samples per cycle $\Rightarrow$

$\Rightarrow$
Sampling frequency - example

Sampling requirements Example 2

Antialiasing filter \( f_c = 90\text{Hz} \)

\[
f_s \geq 2 \cdot f_c \rightarrow
\]

\( 3 \) samples/cycle

Minimal sampling 3 samples/cycle

Logical minimal sampling 4 samples/cycle

4 samples/cycle = 240 Hz

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Sampling requirements Example 3

First and second harmonic \( \rightarrow f_s = 120\text{Hz} \)

Antialiasing filter \( f_c = 180\text{Hz} \)

\[ f_s \geq 2 \cdot f_c \rightarrow f_s \geq 360\text{Hz} \]

\( \rightarrow \) Minimal sampling 6 samples/cycle
Logical minimal sampling 8 samples/cycle
4 samples/cycle = 480 Hz
Input Range

- Bipolar range
- Unipolar range (half or range DC offset should be added)

Voltage levels:

±1V
±5V
±10V

Maximum magnitude of the input signal should be in the full input range of the AD converter
Data Interface

- Parallel
  - byte wide
  - word wide

- Serial
  - SPI
  - I2C
  - Microwire
A/D Converter implementation

- Successive-approximation ADC
- Direct conversion ADC or flash ADC
- Sigma-Delta ADC
- Delta-encoded ADC
- Ramp-compare ADC
- Pipeline ADC or subranging quantizer
Successive-approximation ADC

Clock → SAR (Successive-approximation register) → EOC

$D_{N-1}$ → $D_{N-2}$ → $D_2 D_1 D_0$

$V_{REF}$ → DAC → Comparator

$V_{IN}$ → S/H

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Flash ADC
AD Conversion Error

• Quantization error
  - due to the finite resolution of the ADC

• Non-linearity
  - due to physical imperfections

• Aperture error
  - due to the clock jitter (revealed when digitizing a signal - not a single sample)
Quantization error

4 bits

8 bits
µP and I/O Interface

- CPU
- Memory
- Interfaces
Microprocessor - block diagram
Memory

• Volatile memory - RAM
• Nonvolatile memory – EPROM, Flash

Computer relays are able to keep few dozens (10-100) oscillography recordings and hundreds event files

Nonvolatile memory is used for settings storage
I/O Interface

• CT and PT Inputs
  Nominal current 5 A or 1A, input 0 - 20*Inom
  Nominal voltage 67V, input 0 - 300V

• Control Inputs (24 – 250 V DC/AC)
  Direct Coupled
  Optoisolated

• Control Outputs
  Standard (Break Capacity 0.5A, 6ms)
  Hybrid (Break Capacity 10A, 6ms)
  Fast Hybrid (Break Capacity 10A, 10us)
Communication Interface

- **Serial Ports** (Telnet, Synchrophasors, DNP3 protocols)
  - RS 232
  - RS 422/485

- **Ethernet** (FTP, Telnet, Synchrophasors, DNP3 LAN/WAN, IEC 61850 etc. protocols)
  - 10/100BASE-T
  - Optic Fiber ST, SC connectors…

- **Time Code**
  - IRIG-B Input—Serial Port
  - IRIG-B Input—BNC
  - 1PPS Optic Fiber or BNC
Communication Interface
User Interface

- Knobs
- Lights (LED)
- Displays (LCD)
- Switches
- Thumb Wheels
- Serial interfaces
  - Screen (CRT, LCD)
  - Hand Held Keyboard

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User Interface - example
User Interface - example
User Interface - example
User Interface - example
User Interface – handheld keyboard
Self Testing Techniques

• ROM
• RAM
• Power Supply
• A/D Conversion Time
• Settings
• Analog Gain and Offset
Technology

- MOS (CMOS Microprocessors)
- Bipolar (S/H Amplifiers, Contact I/O)
- Mixed (S/H Amplifiers, Multiplexers)
- Discrete (Signal Conditioning, Surge Filters)
Hardware Architecture

LPF – low Pass Filter
S/H Sample and Hold
PGA- Programmable Gain Amp.
Software

- Application software
  - Modules
  - Implementation
- System software
- Operator Int. Software
- Communication Software
  - Serial
  - LAN
System Software

- Self-checking
- Fault Diagnosis
- Module for Synchronization
Distance Relay Measurements

• Type of Fault

• Switched Scheme
  - Fault type analysis
  - Check all fault loops
  - Fault type change check
  - Completion Check

• Polyphase Measurement Method
  - Executing all distance measurements
  - Symmetrical components method
  - Other polyphase calculations
Program for focused distance relaying

Non fault tasks → Disturbance detector checks → Possible Fault?

Fault type analysis → Fault type identified?

Focused disturbance processing → Fault confirmed in some zone?

Issue trip or control command → Fault type change check → Change seen?

Focused checking done? → Completion check → Fault found?
Application Software

- Monitoring of input quantities
- Fault detection
- Fault classification
- Calculation of relaying quantities
- Fault verification
- Tripping
- Restoration of monitoring function