Dataflow programming languages: LabVIEW

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Data-flow: interconnected functional units

Programs are made of functional units connected by wires

- **wires represent data exchanges (i.e. variables)**
- **they are typed (a different colour/shape for each wire)**
- **multiple data can be aggregated in a single BUS (i.e. a record / struct)**
- **each functional unit has a default GUI for testing its I/O**

Modularity

- **functional units can be defined and reused**
- **circuits/networks can be packaged as new functional sub-units**

LabVIEW

Created in 1986 by National Instruments to interact with and manage digital data-acquisition electronics and control systems

Modelled over the circuit design and testing metaphor (you draw a circuit)

Each functional unit in the graphic language runs as soon all its input data are available

Multiple cores and threads are used to schedule the parallel execution of multiple active units

Programs are compiled into an intermediate “G” language
(but can also be compiled to native code)

You normally (need to) add explanation boxes to document your ideas

Free LabView Community edition available for personal usage

Circuit metaphor

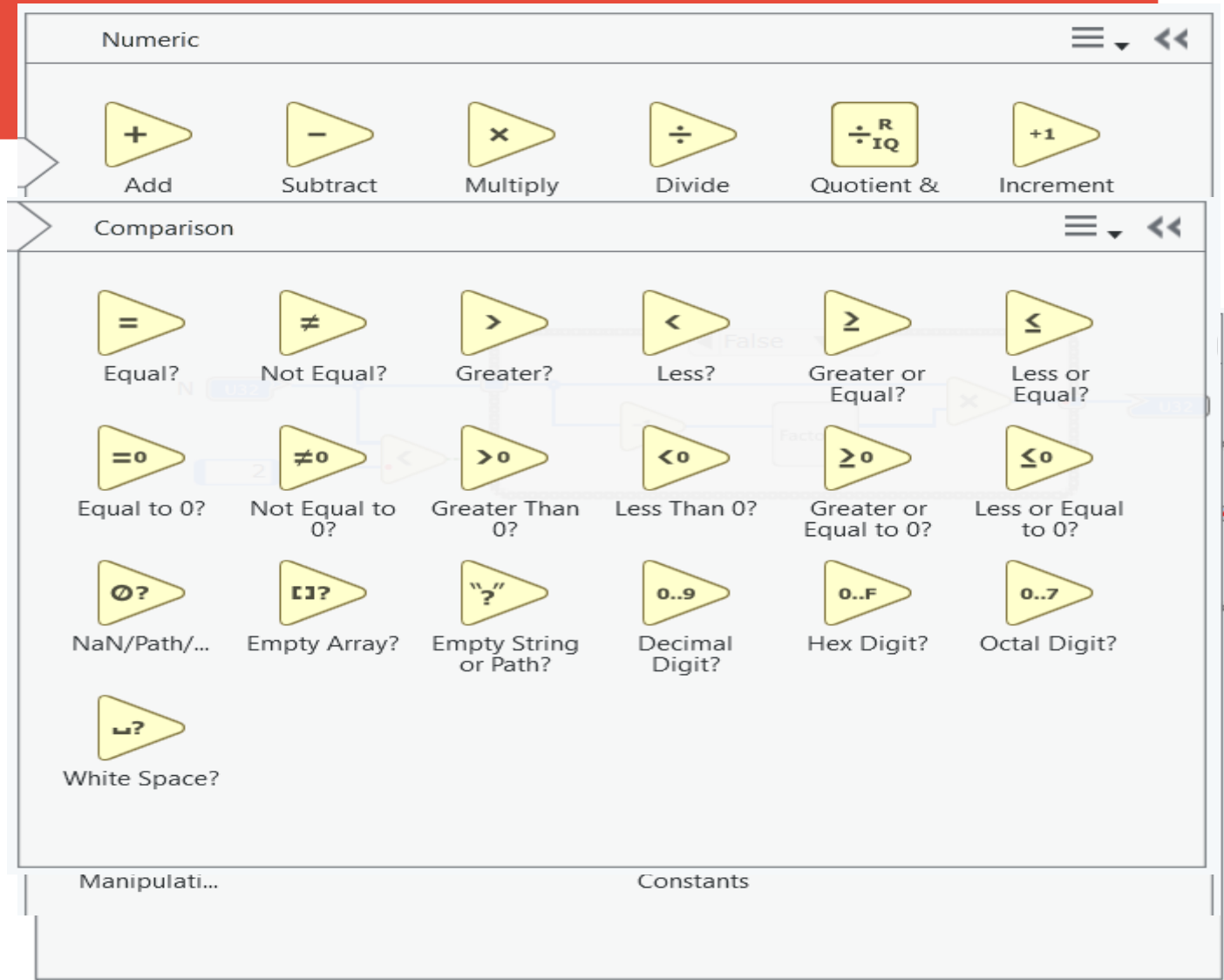
PROGRAM	==>	CIRCUIT
VARIABLE	==>	WIRE
TYPE	==>	WIRE COLOUR (or type)
FUNCTION	==>	CIRCUIT COMPONENT (defined with a sub-circuit and its GUI)
ARGUMENTS	==>	INPUT CONNECTORS (input widgets in the GUI)
RETURN VALUEs	==>	OUTPUT CONNECTORS (display widgets in the GUI)
IF-THEN-ELSE	==>	MULTIPLE CIRCUITS (one per condition, but with same I/O wires)
LOOPS	==>	REPEATING CIRCUITS (with stop & state connectors)
CONCURRENCY	==>	IMPLICIT in the data-flow execution (run when input ready)

Functional units

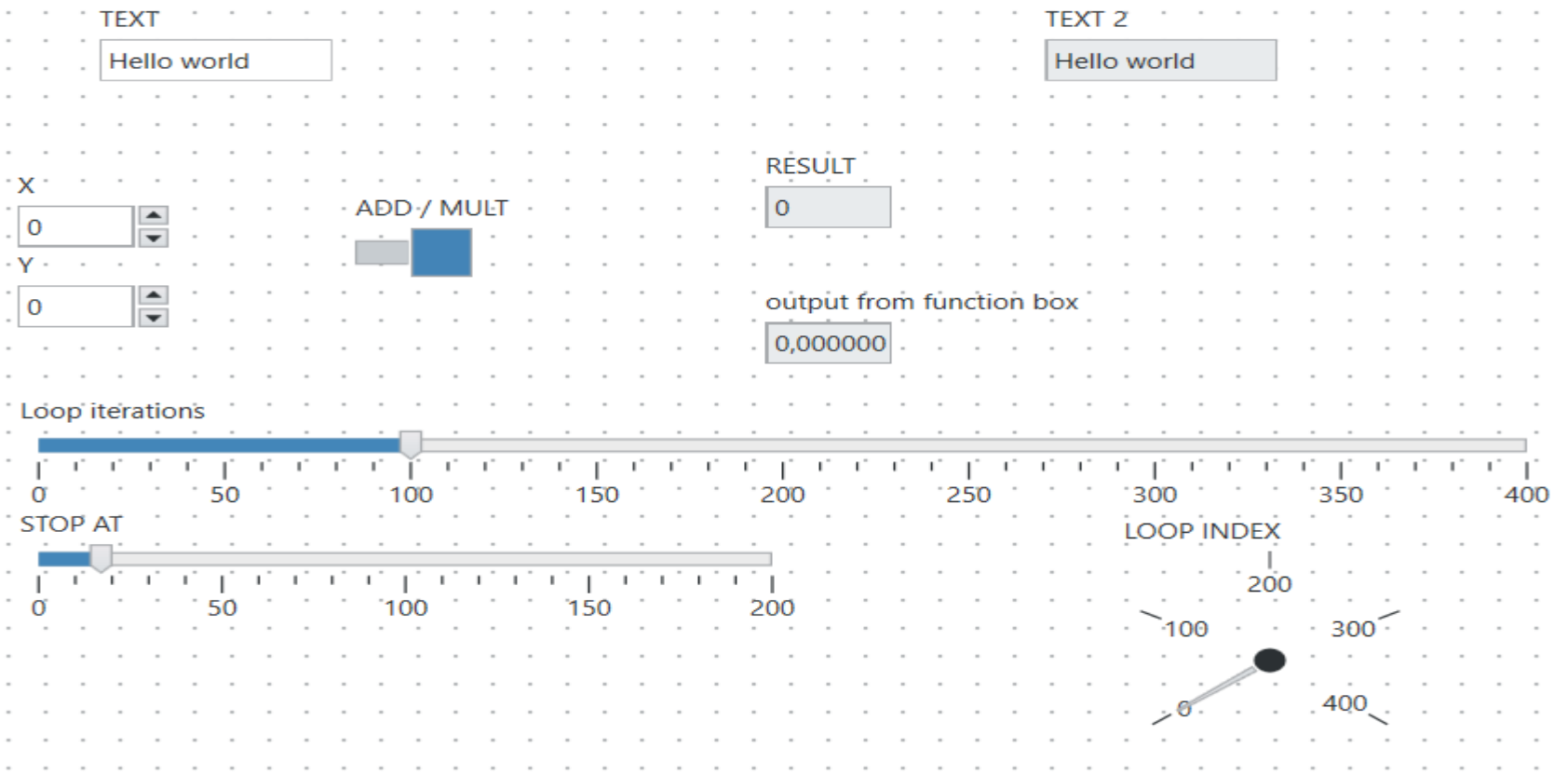
Many numeric and signal processing elements

Multiple values can be bundled in buses

Wires have types



Each functional unit has a default GUI to test it
many widgets are available to personalize it (active or read-only)



Data types describe what a wire could transfer (i.e. the content of the variable)

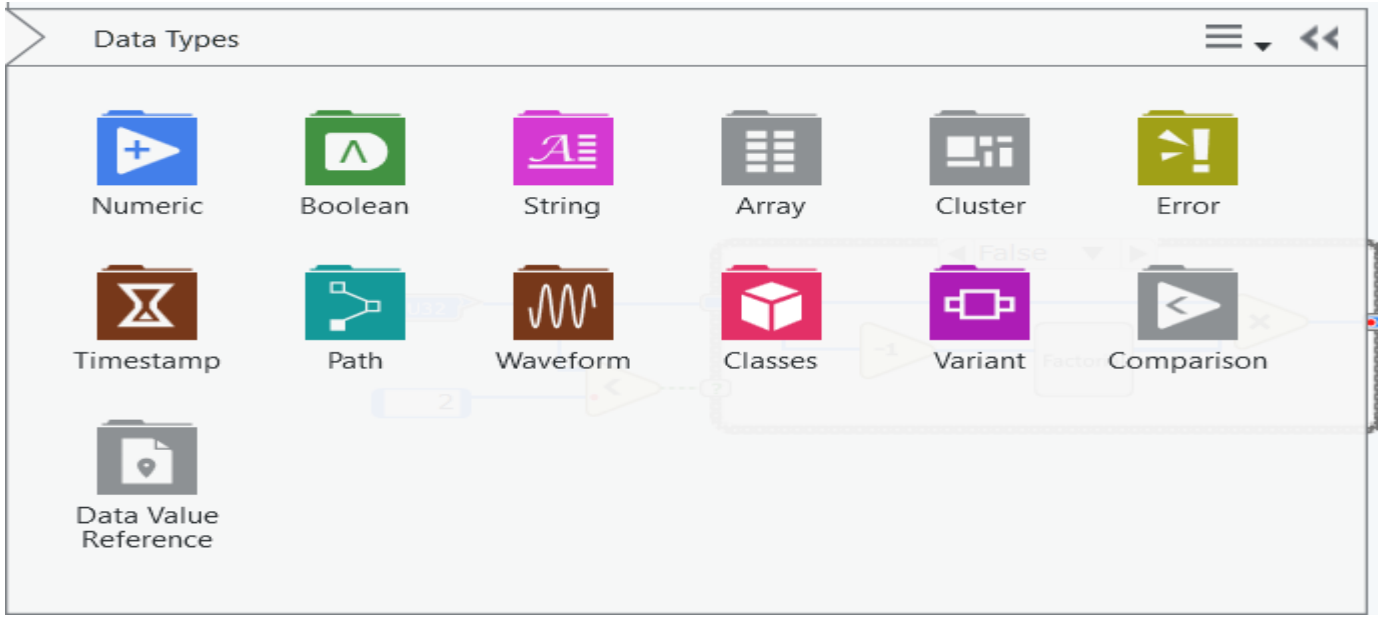
Many numeric types (to interface with hardware and to do signal processing)

Strings

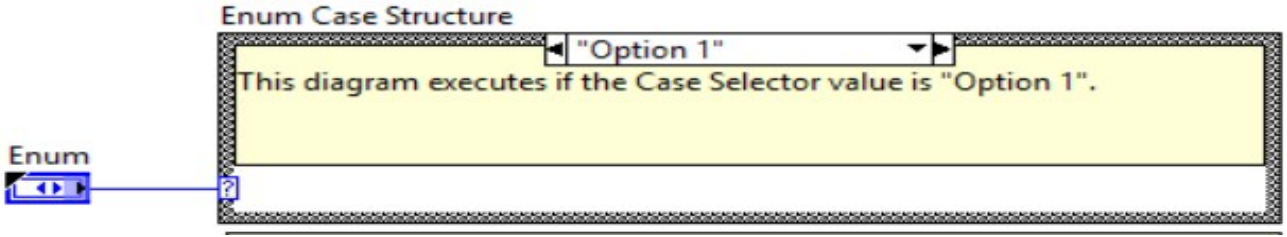
Arrays, records, structs (Clusters)

Classes

…



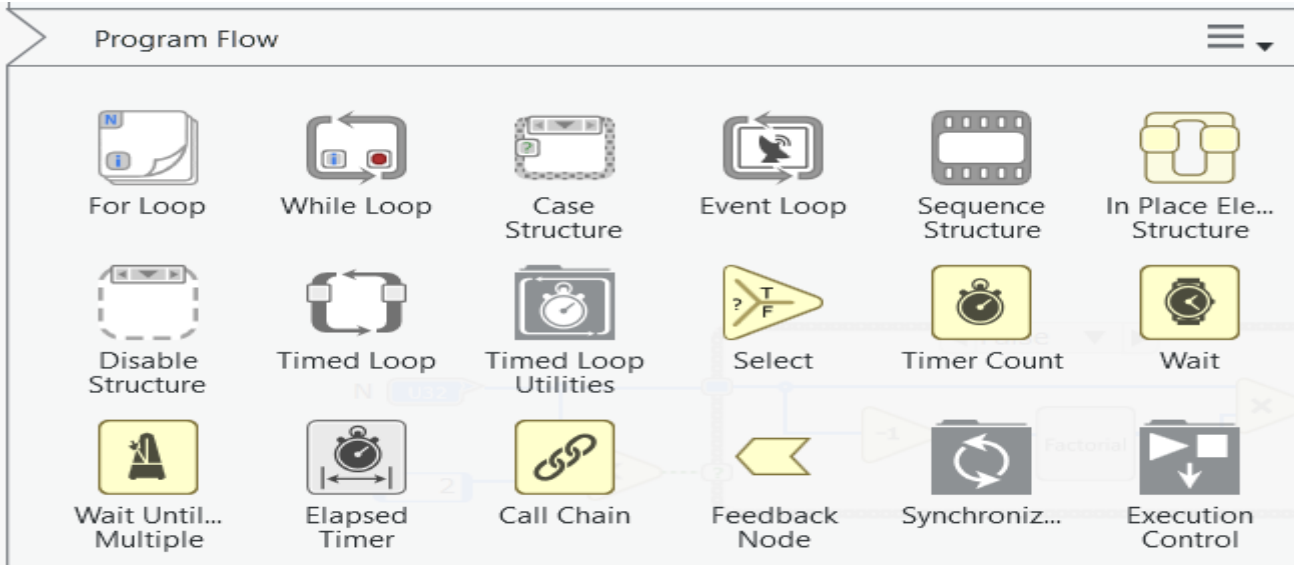
Control structures and scope



Control structures are represented as boxes

- **on the border there is a conditional / control input connector**
- **the box is the equivalent of a group of parentheses (one per case)**
- **multiple cases (if-then-else, switch-case) become “pages”**
- **the box title contains the options of the case / condition**
- **all “pages” share the same external inputs / outputs**
- **control values (e.g. index) are available in all pages**

There are also boxes for formulas or external code (ASM/C/C++)



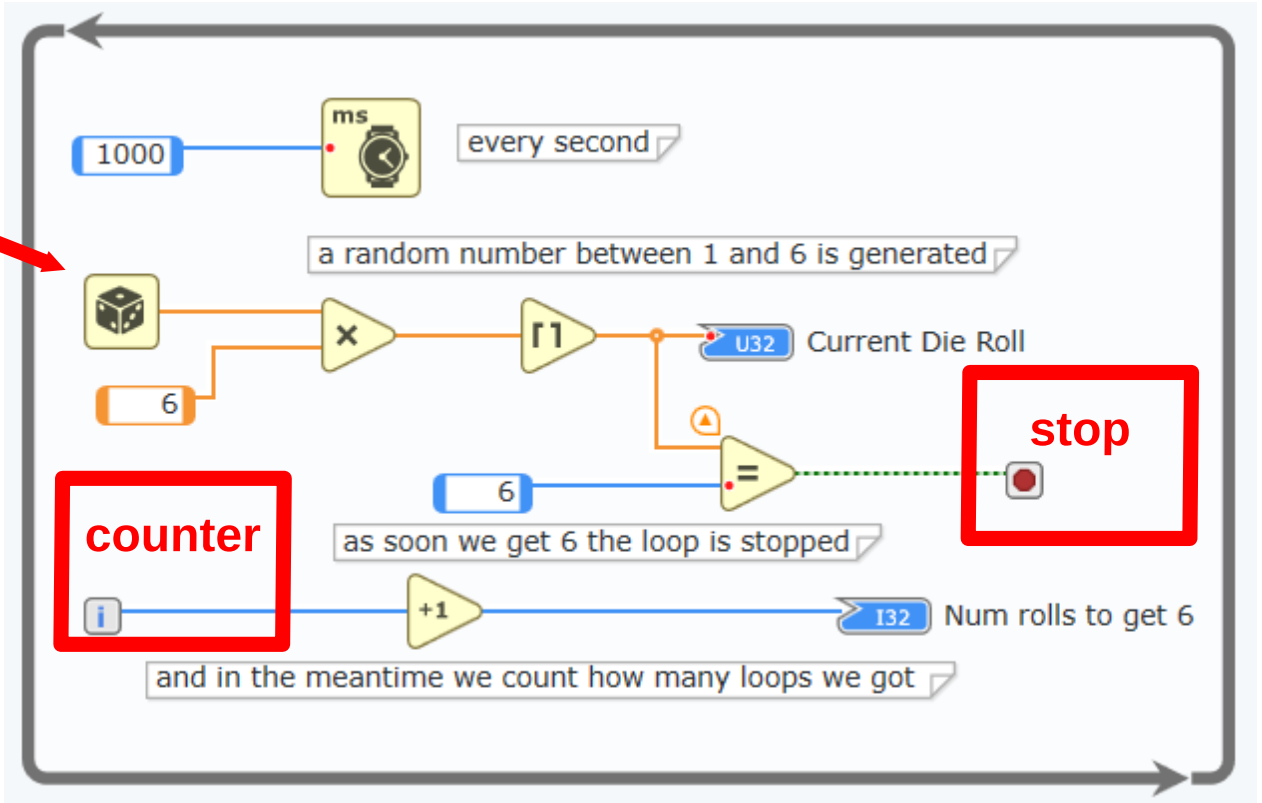
While loop example

The dice unit generates floats from 0 to 1

We multiply by 6 and take the ceiling

We **stop** as soon we see a 6

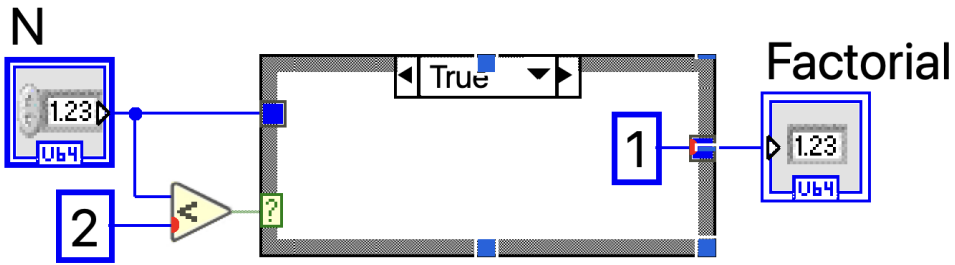
The **counter i** starts from 0

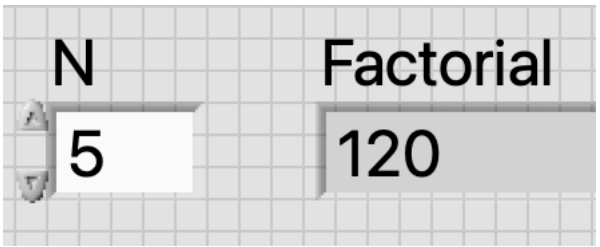


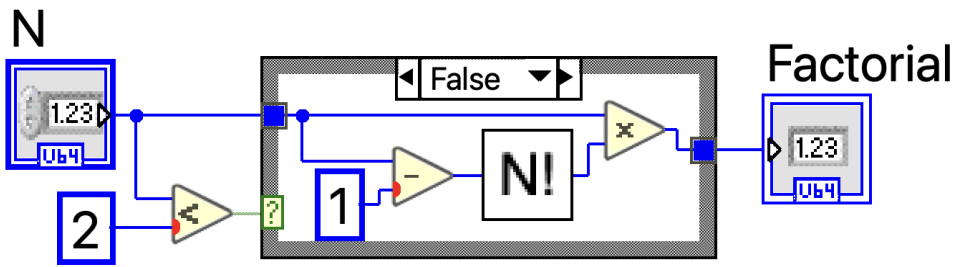
Recursion? YES

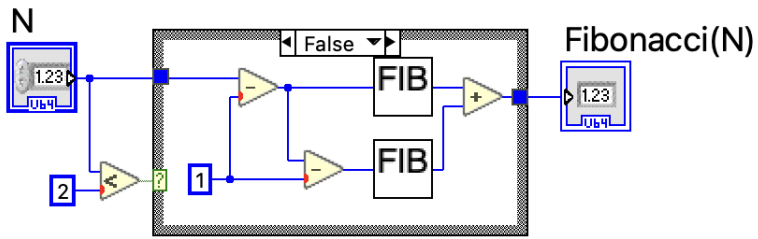
1) Define a block as “reentrant” (i.e. allowing multiple parallel copies)

2) Then you can call it inside the same block or one of its sub-blocks









Examples: Factorial, Fibonacci

NOTE: you can define “code” blocks in C or other languages or call external DLLs

Concurrency? YES (depends on how parallel is your circuit)

Synchronization

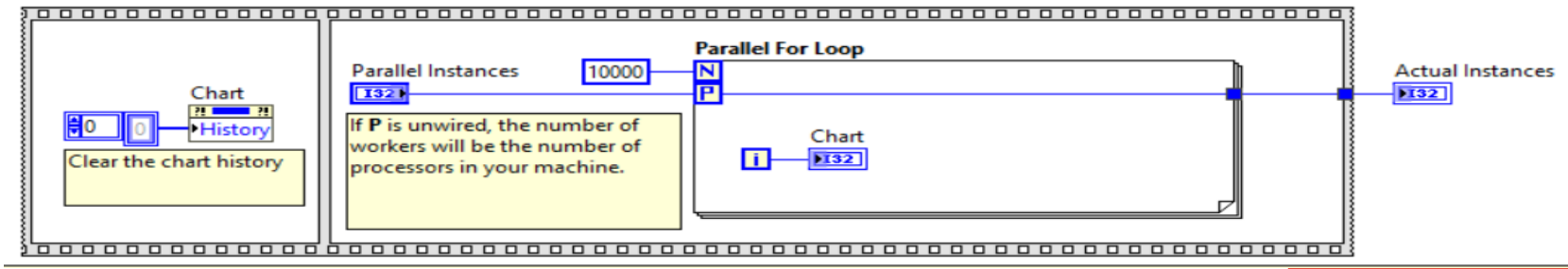
- a block starts computing when <u>all its input data is available</u>

This produces an inherently parallel data-flow implementation

- linked units must run <u>sequentially</u> because of <u>data dependency</u>
- NON-linked units <u>run in parallel</u> (emulated or on available cores)

Sequencing constraints can be implicit or explicit

- implicit: from data dependencies (links induce time order)
- <u>explicit</u>: you add time dependencies without data exchange with the construct below



LabView programming style

Data-flow visual design

- **Visual construction of the data-flow circuit diagram**
- **Visual test of the diagram**
  - **all blocks have their GUI showing IN/OUT data**
  - **add probes to show internal wires' values and to plot changes vs time**

Inherently parallel (you just forget about sequentiality constraints)

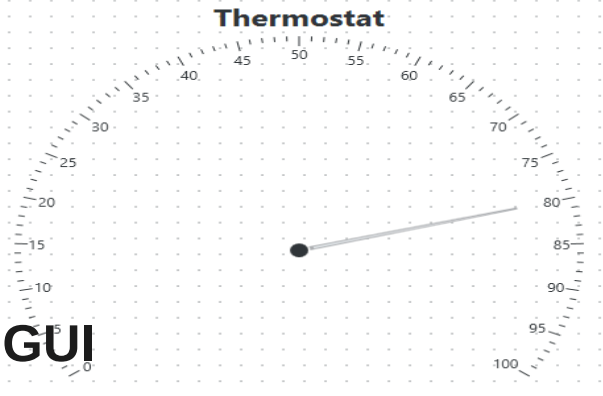
Object-Oriented (classes)

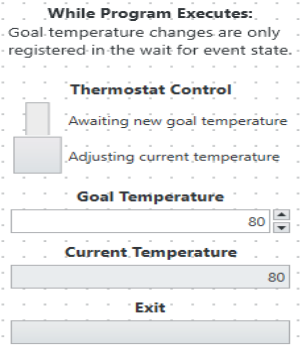
Interaction with other systems:

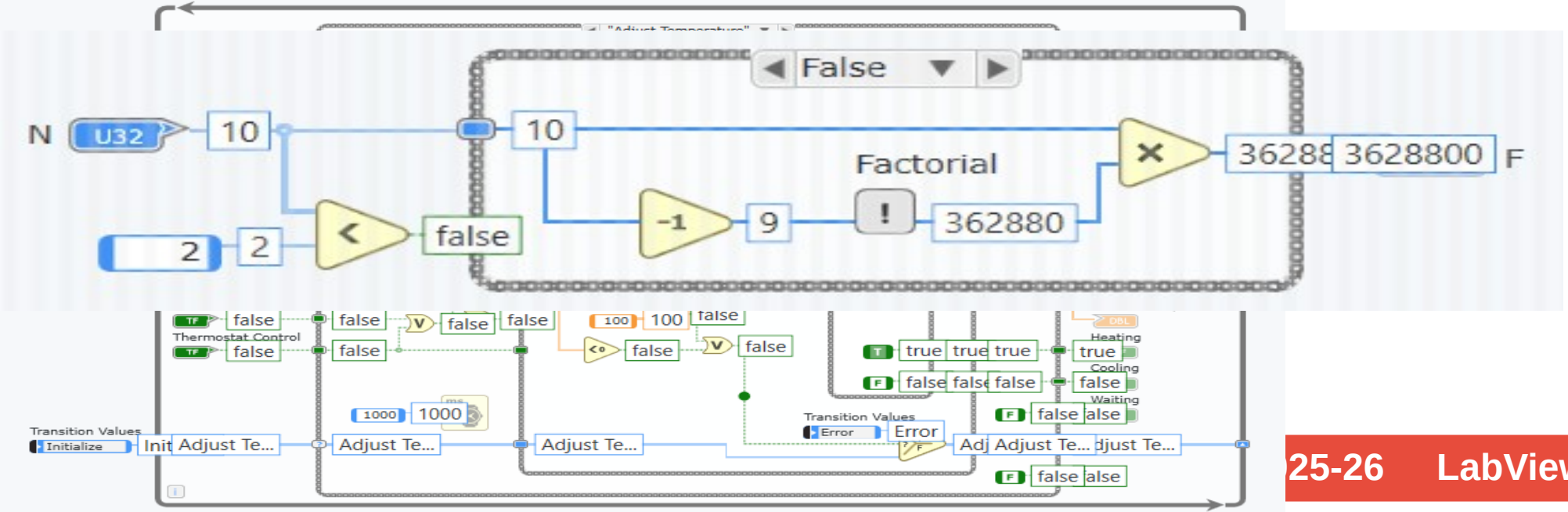
- **Function blocks for data math manipulation**
- **Code blocks for special algorithms in C++ or Fortran**
- **Many libraries for Statistics, Signal analysis/manipulation, Math**

Debugging

Visual tracing of data on wires
GUI for blocks IN/OUT
Probes on wires show as widgets on GUI
Values are shown on wires







LabView for teaching Computational Thinking?

PRO

- radically different way to “think” a program
  perhaps suited for deaf/DSA students?
- implicit concurrency
- some problems map naturally to circuits
  (e.g. signal analysis/generation)
- easy definition of feedback control systems
- easy interaction with robots or Arduino
- compiled programs can run inside Lego EV3
  or other microcontrollers

CON

- radically different way to “think” a program
- some algorithm is hard to map to circuits (e.g. symbolic problems, text analysis, …)

TLDR: good for electronic/technical schools

Demo

DEMO