Hands-on Workshop Introduction to Electronics

Monica Ignat – **Applications Engineering Manager**

analog.com

Who are we?

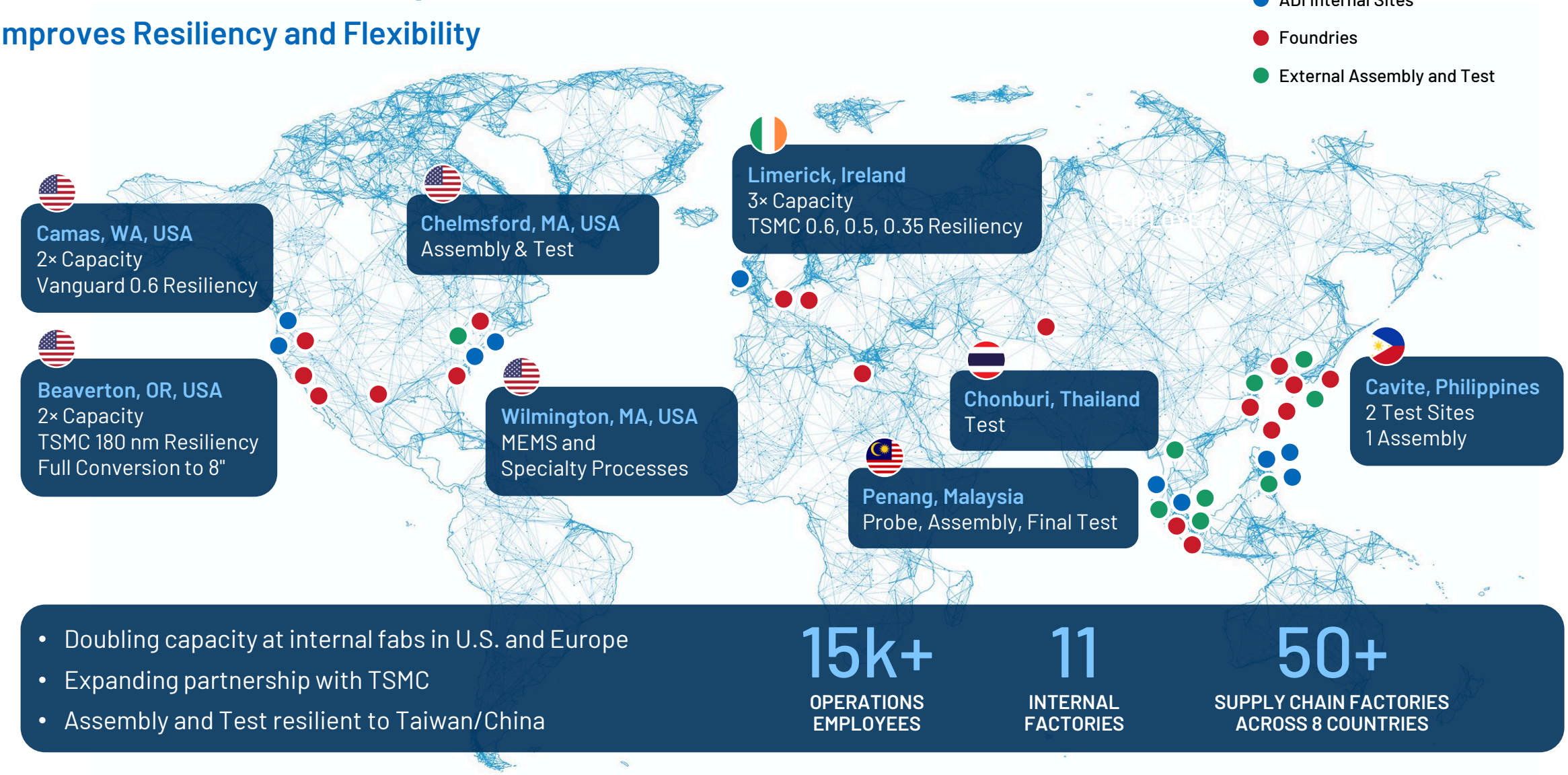
Founded	**1965**
Headquarters	**Norwood, MA**
Employees	**~15,000**
Countries	**20+**
Products	**~45,000 SKUs**
Customers	**125,000**
Publicly Listed	**NASDAQ:ADI** Part of S&P 500 and NASDAQ 100
Design Centers	**~45**
Global Manufacturing	**U.S. (Massachusetts, California, Washington), Ireland, Philippines, and Malaysia**

Over 4700 patents and $4 billion R&D investment in the past 10 years.

Technologies for Today's and Tomorrow's Innovations

ADI's Global Footprint

Improves Resiliency and Flexibility



- Doubling capacity at internal fabs in U.S. and Europe
- Expanding partnership with TSMC
- Assembly and Test resilient to Taiwan/China

15k+
OPERATIONS EMPLOYEES

11
INTERNAL FACTORIES

50+
SUPPLY CHAIN FACTORIES ACROSS 8 COUNTRIES

Worldwide Offices

1/17/2025

ADI Romania Design Center

Founded in 2011

Office 1 - UBC Riviera

- 1,000 square meters, 100 people capacity

Office 2 - UBC Tower

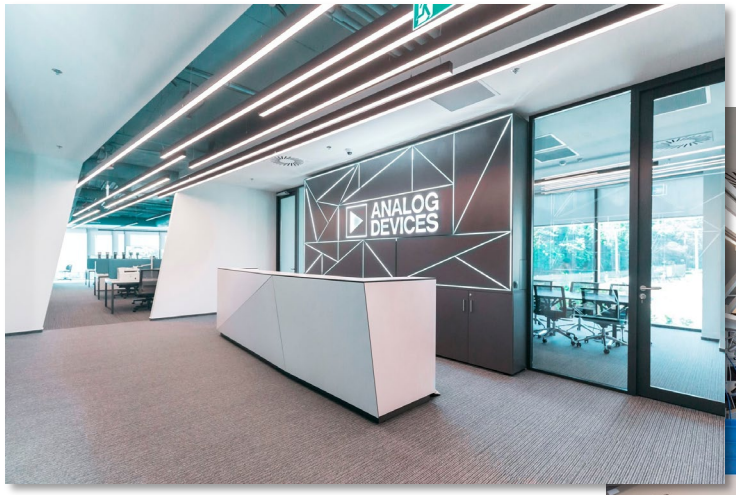
- 1,000 square meters, 120 people capacity

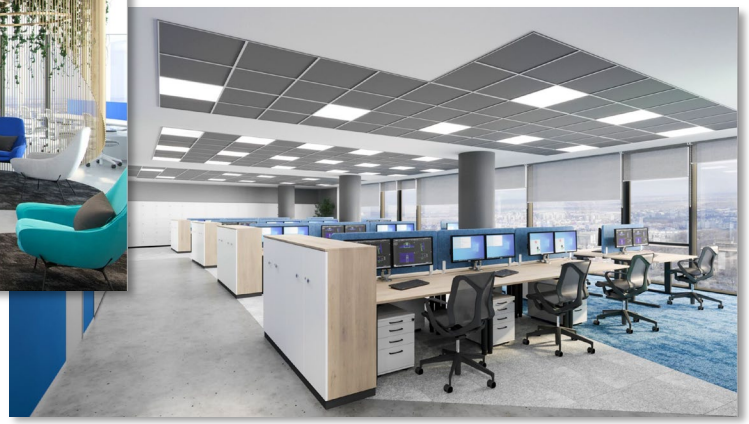
Multidisciplinary team

- Hardware design
- FPGA development (VHDL, Verilog)
- Embedded software (C/C++, Linux)
- Applications software (Python, MATLAB, C++)
- Devops (Jenkins, Microsoft Azure, CI/CD)
- System architecture
- UX design
- Program/Project management

Project fields

- RF Communications
- Precision & High-Speed Instrumentation
- Depth, Perception and Ranging (ToF, LIDAR)
- Industrial Automation





Agenda

Part 1

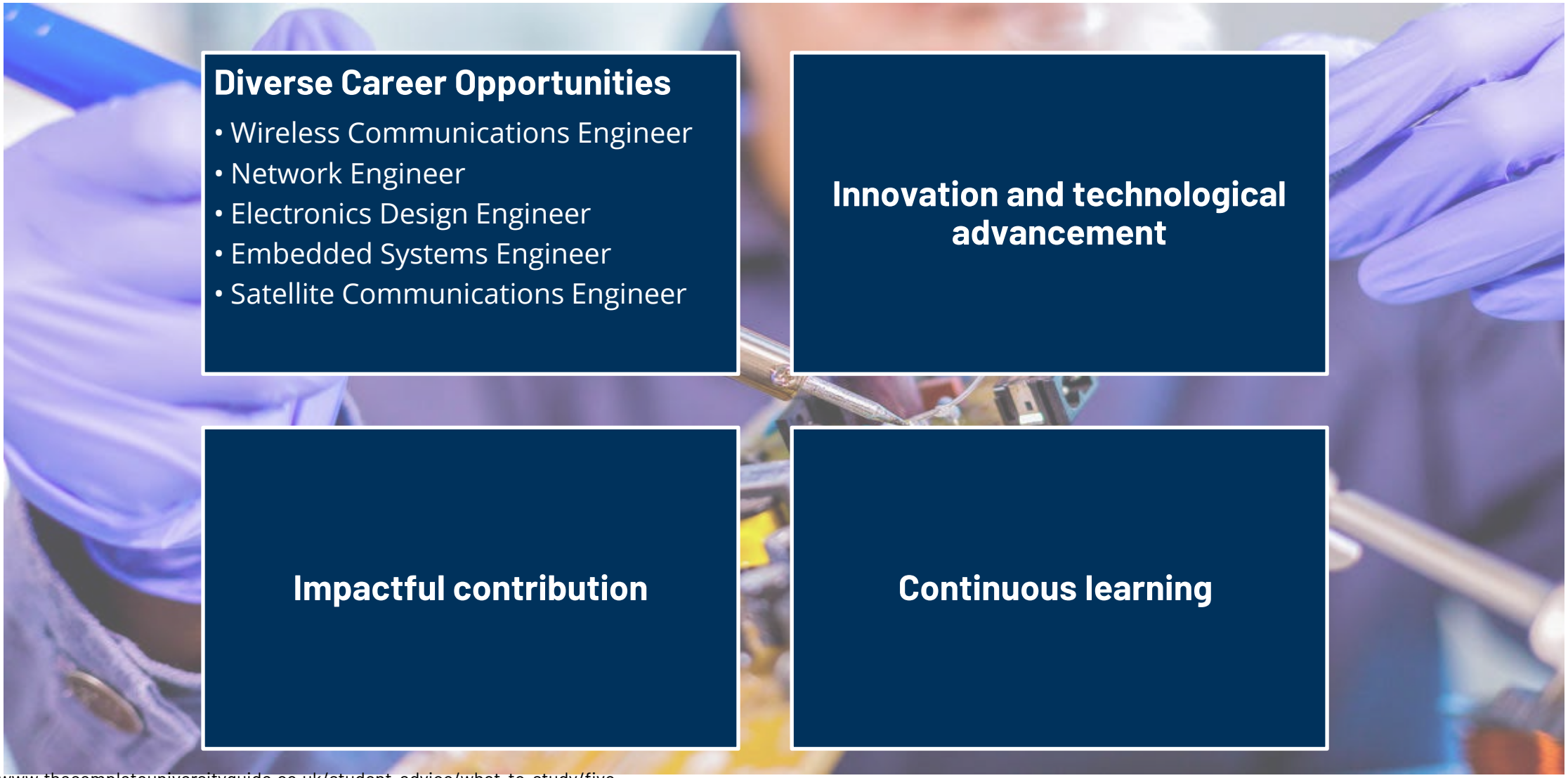
- Why Electronics?
- What is an IC
- Transistors – what kind of species is that?
- How many transistors are needed to create a logic gate?
- Academic Resources - Introduction to ADALM2000

Part 2

- Demos
- Q&A session

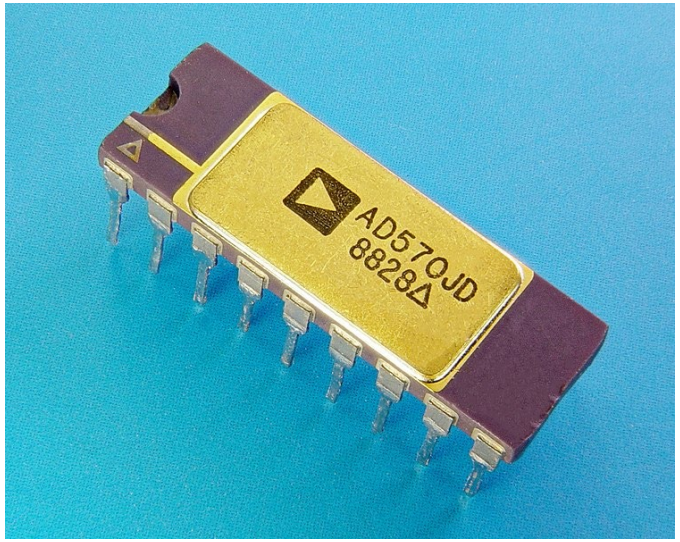
Hands-on Workshop: Introduction to Electronics Part 1

Why electronics?



https://www.thecompleteuniversityguide.co.uk/student-advice/what-to-study/five-reasons-to-study-electrical-and-electronic-engineering

What is an IC?



https://en.wikipedia.org/wiki/File:AD570JD.jpg

IC

- An integrated circuit (IC) is an assembly of electronic components in which hundreds to millions of transistors, resistors, and capacitors are interconnected and built up on a thin substrate of semiconductor material (usually silicon) to form a small chip or wafer. Integrated circuits are the building blocks for most electronic devices and equipment.

https://www.arenasolutions.com/resources/glossary/integrated-circuit/

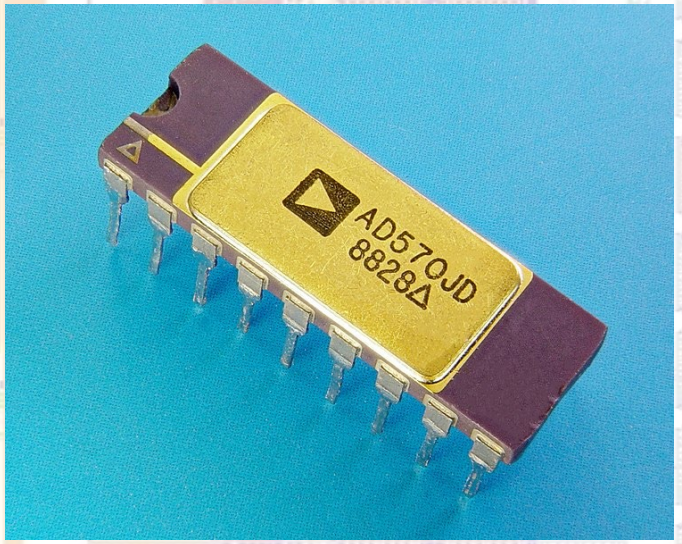
Applications

- **Consumer Electronics**: Smartphones, computers, and home appliances.
- **Industrial**: Automation systems, robotics.
- **Medical**: Diagnostic equipment, wearable health devices.
- **Automotive**: Engine control units, infotainment systems.

Usage importance

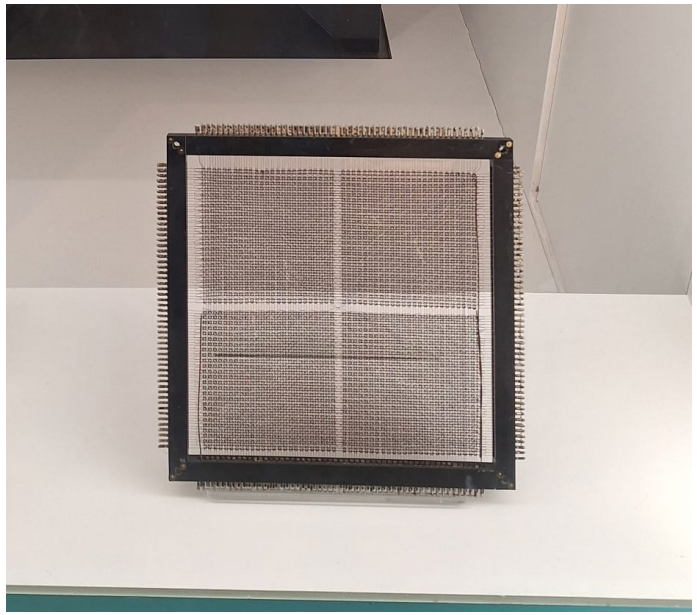
- Miniaturization of circuits.
- Increased reliability and performance.
- Cost efficiency.

What is an IC?

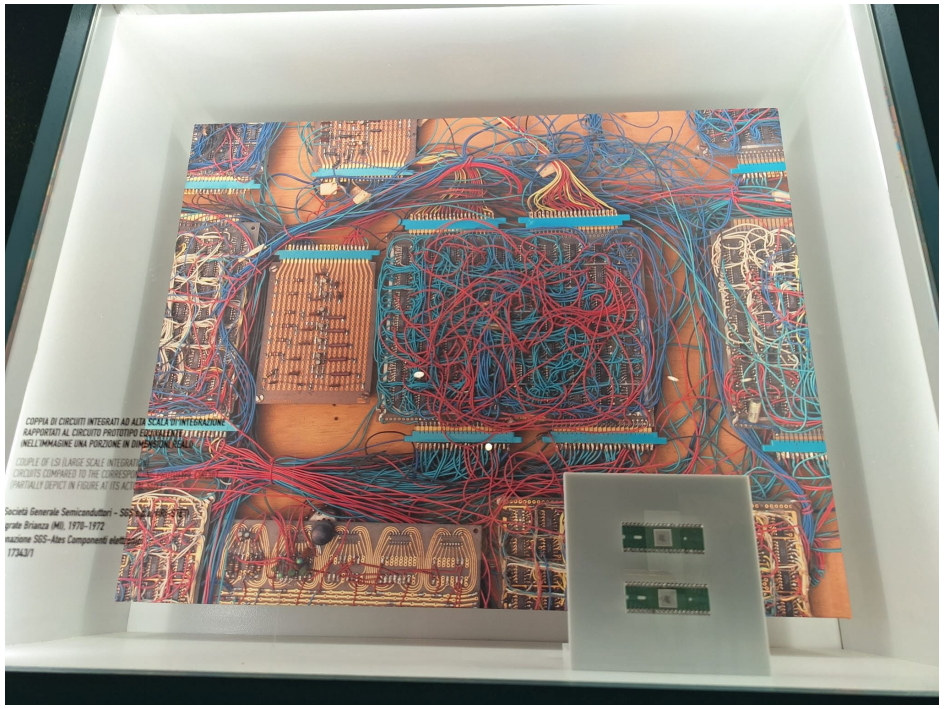


https://www.build-electronic-circuits.com/integrated-circuit/

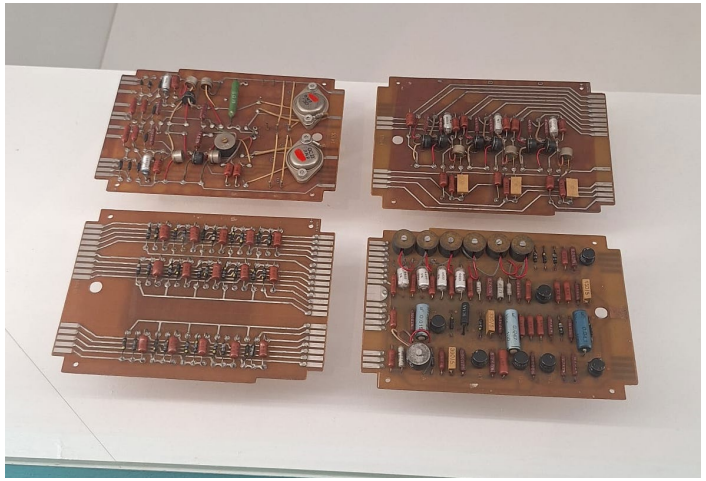
What is an IC?



Ferrite memory
Random Access Memory



LSI – Large Scale Integration circuits compared to the corresponding prototype circuit 1970-1972



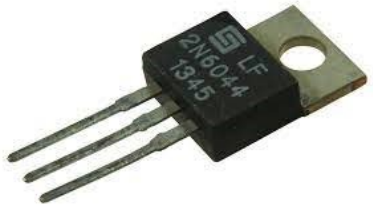
Evaluation Boards

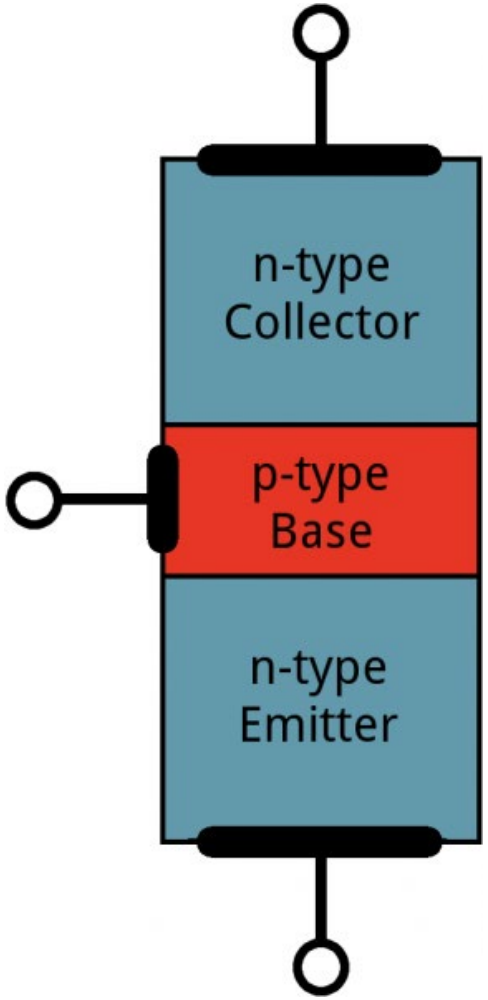
Transistors – what kind of species is that?

Why do we need them?

How do they work?

What are the commonly used types?



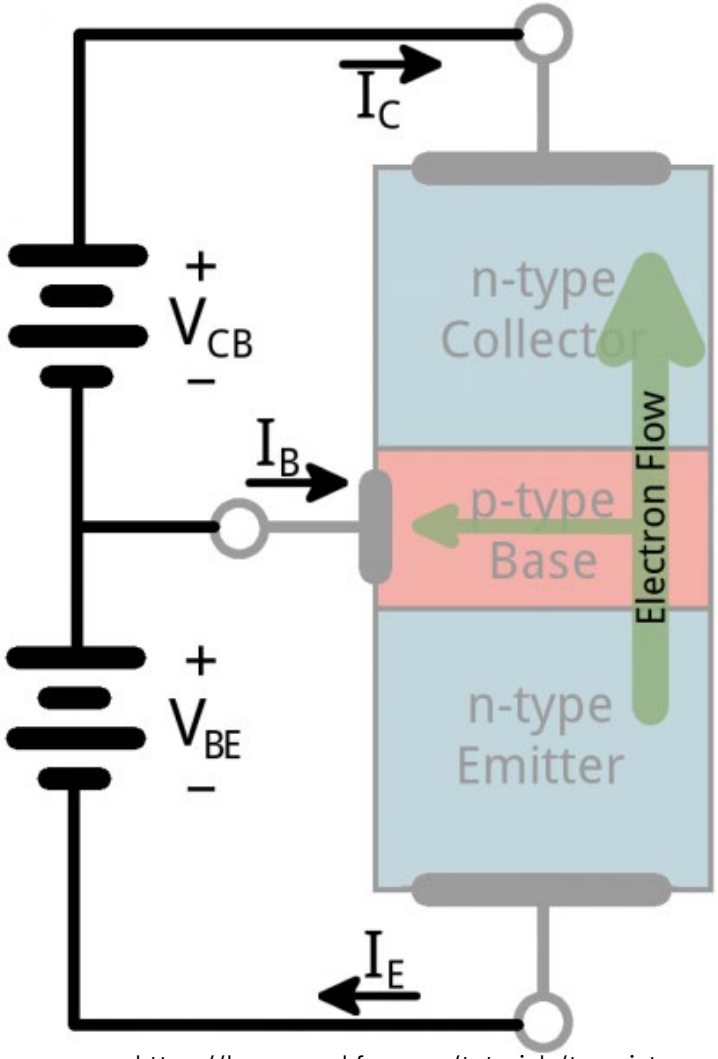


Applications

- **Analog Circuits**: Amplifiers, oscillators.
- **Digital Circuits**: Logic gates, microprocessors.
- **Power Electronics**: Power supplies, motor controllers.

https://learn.sparkfun.com/tutorials/transistors/all

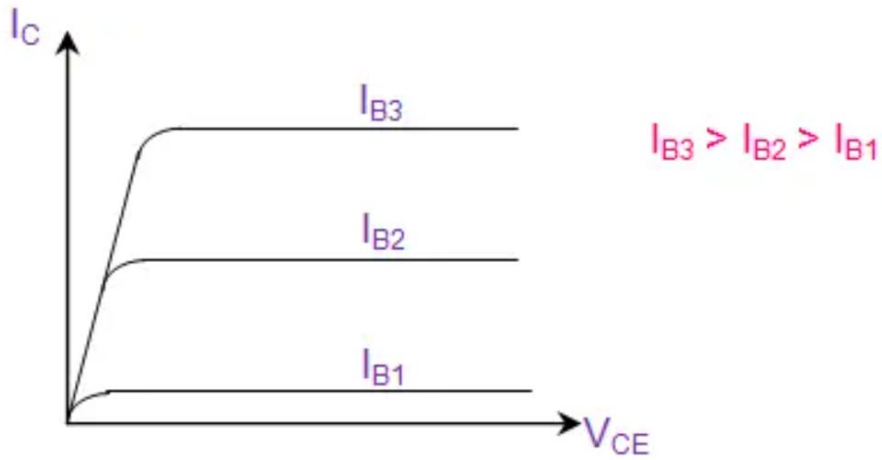
Transistors – what kind of species is that?



https://learn.sparkfun.com/tutorials/transistors/all

Common Emitter configuration output characteristics

$$R_{out} = \frac{\Delta V_{CE}}{\Delta I_C}\Big|_{I_B=constant}$$

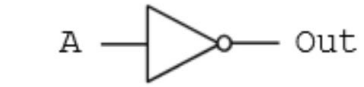


https://www.electrical4u.com/transistor-characteristics/?utm_content=cmp-true

How many transistors are needed to create a logic gate?

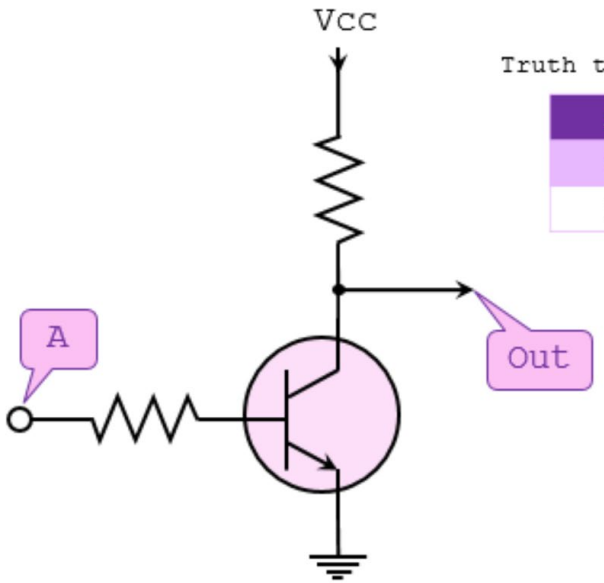
NOT Gate

Symbol:

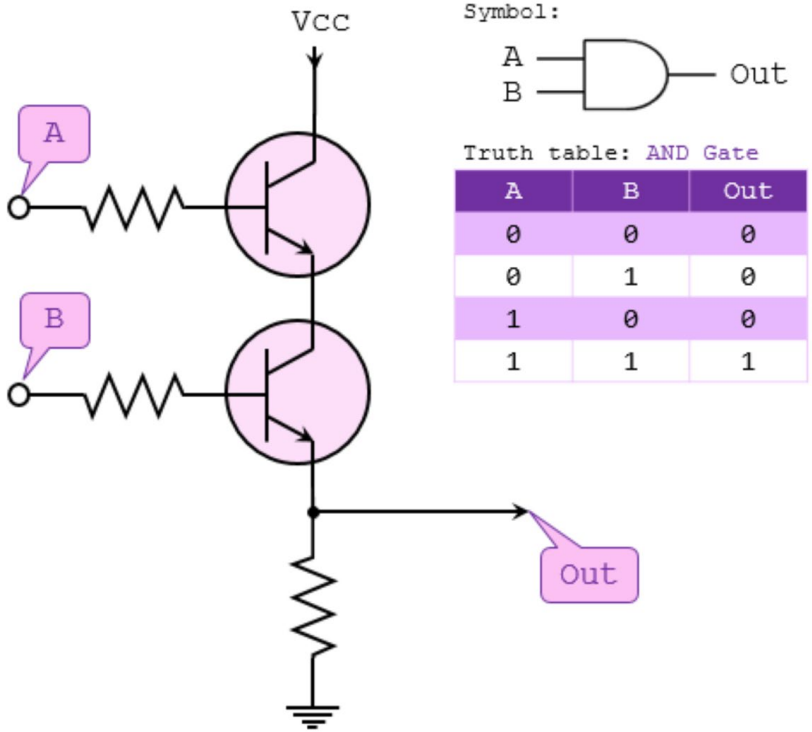


Truth table: NOT Gate

A	Out
0	1
1	0



AND Gate



Symbol:

Truth table: AND Gate

A	B	Out
0	0	0
0	1	0
1	0	0
1	1	1

https://www.101computing.net/creating-logic-gates-using-transistors/

Academic Resources - Introduction to ADALM2000

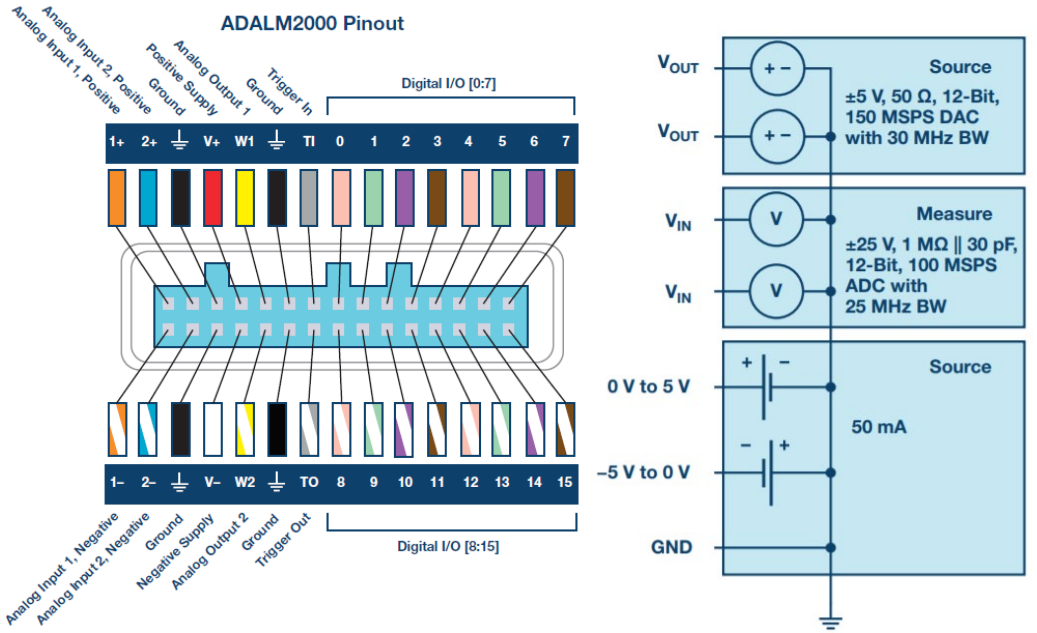
The ADALM2000 (M2K) Advanced Active Learning Module is an affordable USB-powered data acquisition module, that can be used to introduce fundamentals of electrical engineering in a self or instructor lead setting.

With 12-bit ADCs and DACs running at 100 MSPS, brings the power of high-performance lab equipment to the palm of your hand, enabling electrical engineering students and hobbyists to explore signals and systems into the tens of MHz without the cost and bulk associated with traditional lab gear.

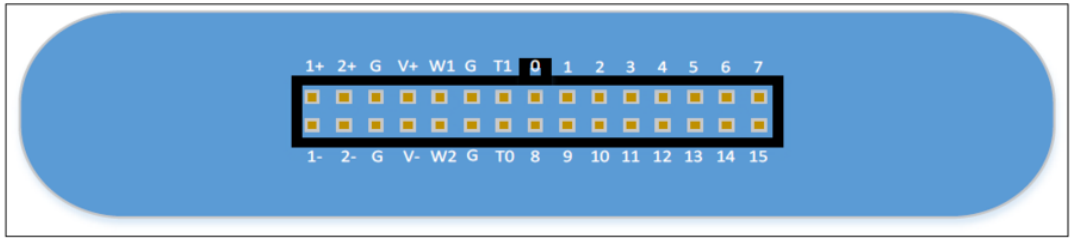
When coupled with Analog Devices' Scopy™ graphical application software running on a computer, provides the user with high performance instrumentation.

ADALM2000 features

- Two-channel oscilloscope with differential inputs
- Two-channel arbitrary function generator
- 16-channel digital logic analyzer (3.3V CMOS and 1.8V or 5V tolerant, 100MS/s)
- 16-channel pattern generator (3.3V CMOS, 100MS/s)
- 16-channel virtual digital I/O
- Two input/output digital trigger signals for linking multiple instruments (3.3V CMOS)
- Two-channel voltmeter (AC, DC, ±25V)
- Network analyzer – Bode, Nyquist, Nichols transfer diagrams of a circuit. Range: 1Hz to 10MHz
- Spectrum Analyzer – power spectrum and spectral measurements (noise floor, SFDR, SNR, THD, etc.)
- Digital Bus Analyzers (SPI, I^{2}C, UART, Parallel)
- Two programmable power supplies (0…+5V , 0…-5V)

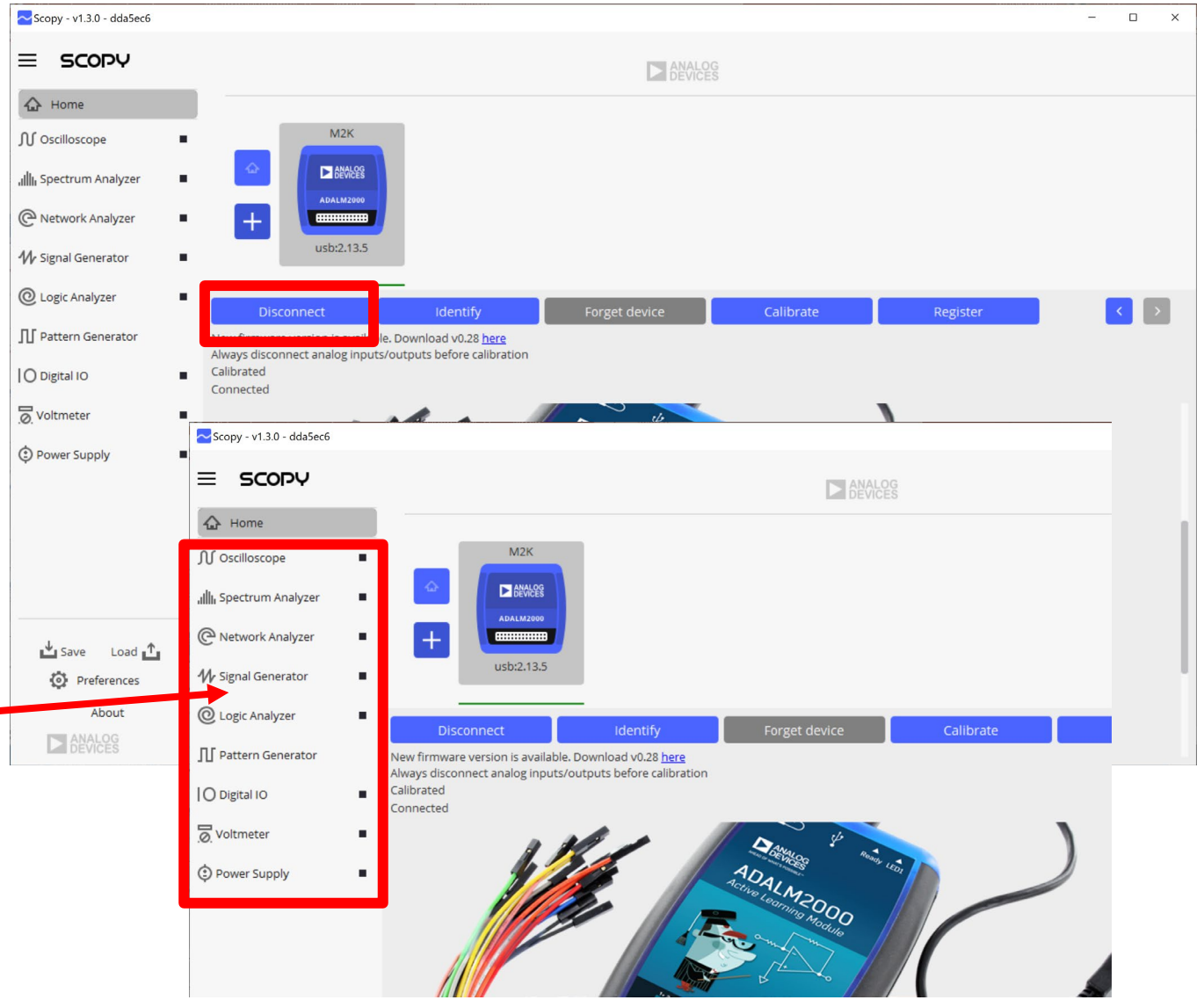


Scope Ch 1 +	Scope Ch 2 +	GND	Positive Supply	AWG Ch1	GND	Trigger In 1	DIO 0	DIO 1	DIO 2	DIO 3	DIO 4	DIO 5	DIO 6	DIO 7
Scope Ch1 -	Scope Ch2 -	GND	Negative Supply	AWG Ch2	GND	Trigger In 0	DIO 8	DIO 9	DIO 10	DIO 11	DIO 12	DIO 13	DIO 14	DIO 15



Scopy

- Install
  - Windows download: [Installer for latest release (Windows 64/32-bit)]
- Connect to a USB or remote device
- Cross platform
- Multiple instruments:
  - Oscilloscope
  - Network Analyzer
  - Spectrum Analyzer
  - Signal generator
  - Logic Analyzer
  - Pattern Generator
  - Voltmeter
  - Power supplies



Hands-on Workshop: Introduction to Electronics Part 2

Hands On Activity

By the end of this **workshop**, you will learn:

- How to use a breadboard
- How to power on an IC
- How to read an IC pinout from datasheet
- How to use a desktop Oscilloscope and Signal generator channels by operating a Network Analyzer
- How to visualize a low pass filter characteristic / transfer function
- How to drive a transistor
- How to create a logic function for performing a specific task

http://www.iconarchive.com/show/noto-emoji-objects-icons-by-google/62807-radio-icon.html
http://www.streamlineicons.com
http://pixelkit.com

Hands On Activity

Equipment used:	• M2K board • ADALP2000 kit components
Demo 1	• Low pass filter transfer function
Demo 2	• Digital demo – traffic lights using logic gates
Demo 3	• Back to the analog world - Transistors
Instructor led demo	• Home made battery

http://www.iconarchive.com/show/noto-emoji-objects-icons-by-google/62807-radio-icon.html
http://www.streamlineicons.com
http://pixelkit.com

Hands On Activity

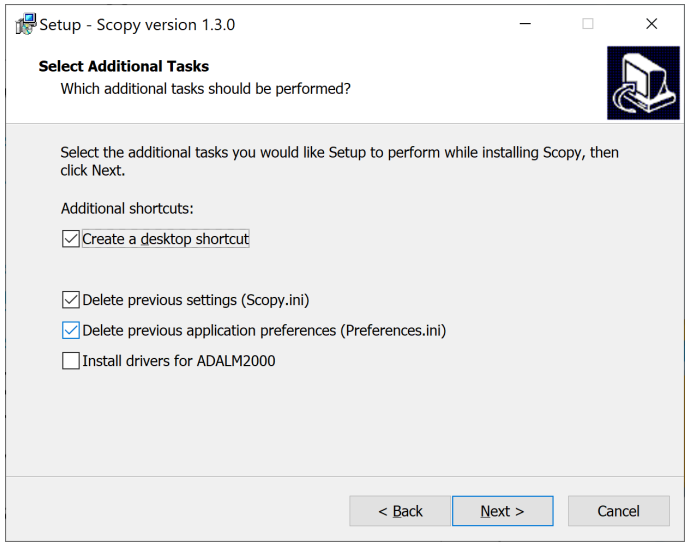
Install windows drivers from: https://github.com/analogdevicesinc/plutosdr-m2k-drivers-win/releases

Install Scopy software from: https://github.com/analogdevicesinc/scopy/releases/download/v1.3.0/scopy-v1.3.0-Windows-setup.exe

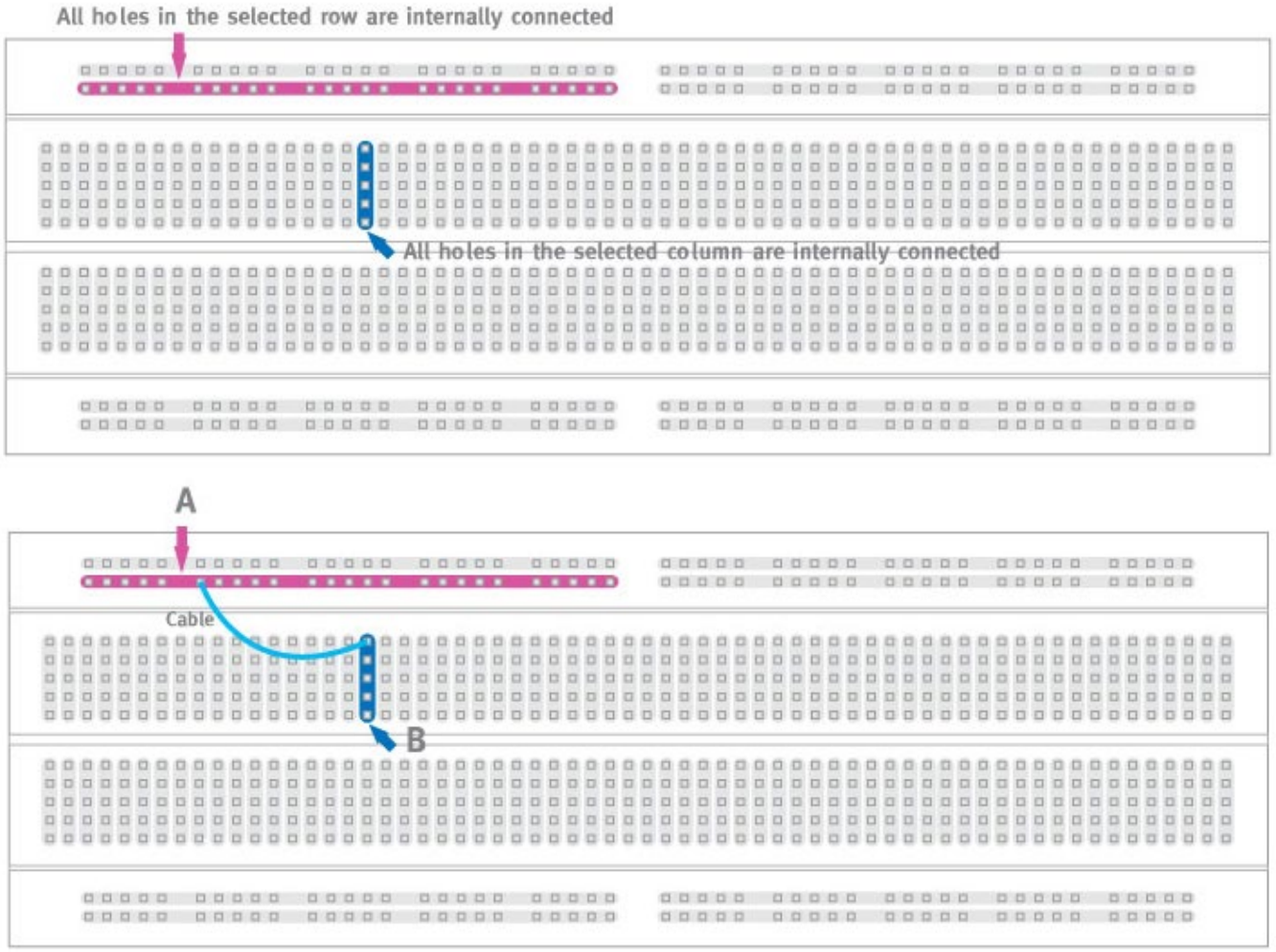
Plug the M2K board in and open device manager – check the board is being recognized and appears there

Open Scopy app

Connect M2K to the Scopy



Hands On Activity



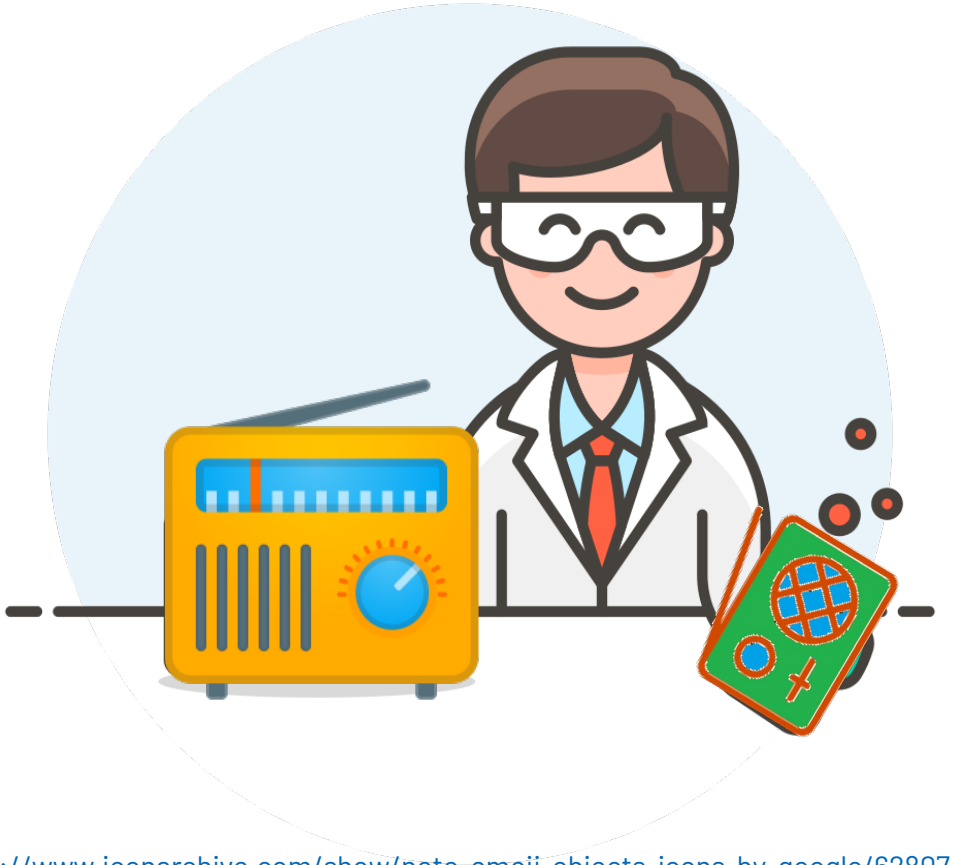
Hands On Activity

Demo 1

Cascaded Low-pass filters – Transfer Characteristics

Materials:

- ADALM2000 Active Learning Module
- Solder-less breadboard
- Jumper wire kit
- 2 pcs 1 KΩ resistors
- 2 pcs 0.1 uF capacitors (marked 104)



http://www.iconarchive.com/show/noto-emoji-objects-icons-by-google/62807-radio-icon.html
http://www.streamlineicons.com
http://pixelkit.com

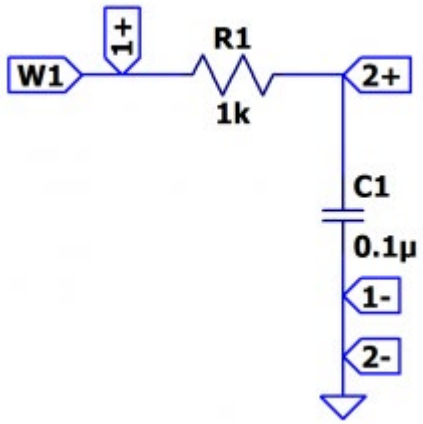
Hands On Activity

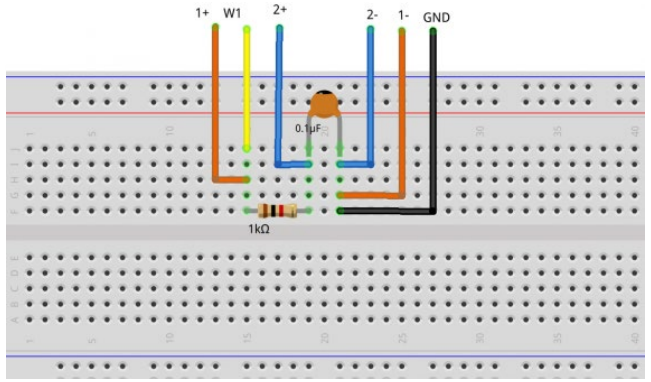
Demo 1

Cascaded Low-pass filters – Transfer Characteristics

First order Low Pass Filter

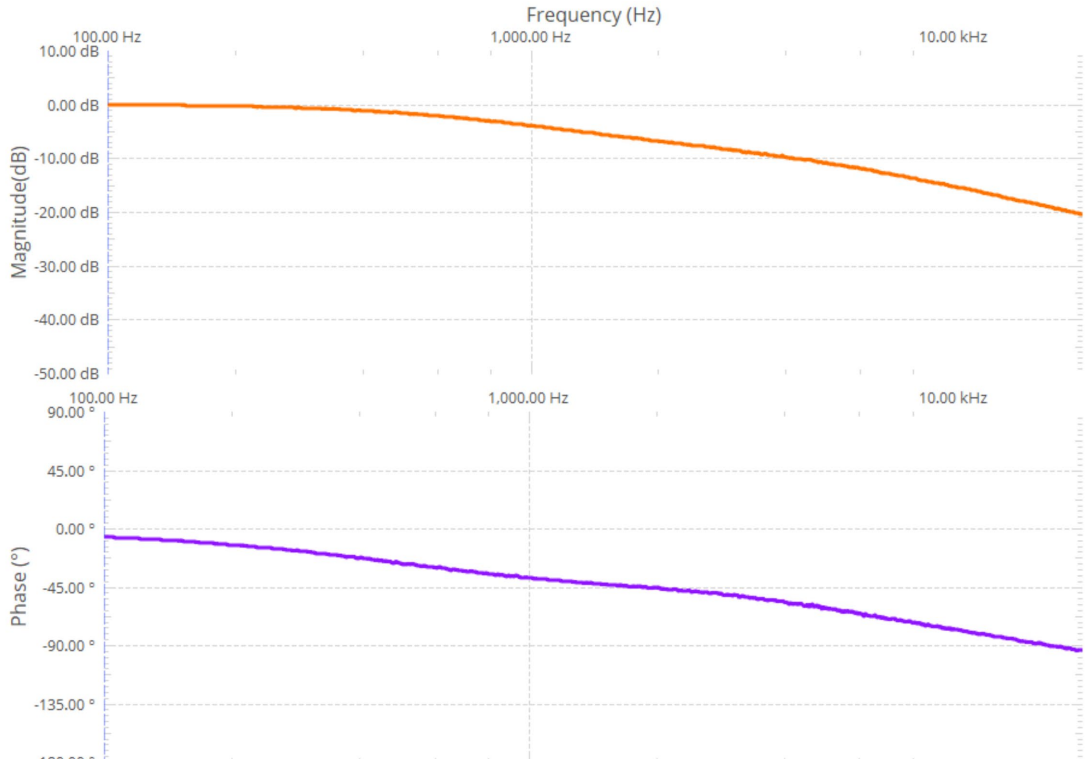
Hardware setup





Procedure:

- Open Network Analyzer
- Set the sweep to logarithmic
- Set the start frequency to 100Hz and stop to 20kHz
- Set the magnitude axis between -50dB and 10dB
- Set the phase axis between -180 and 90 degrees



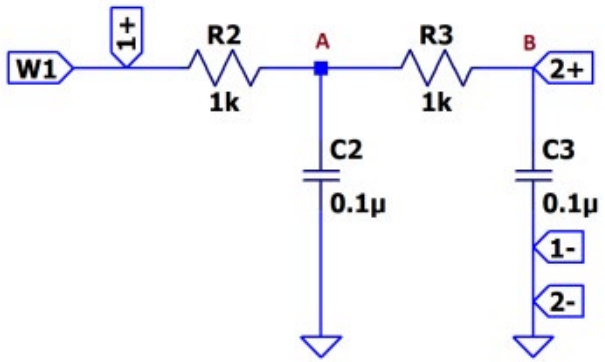
Hands On Activity

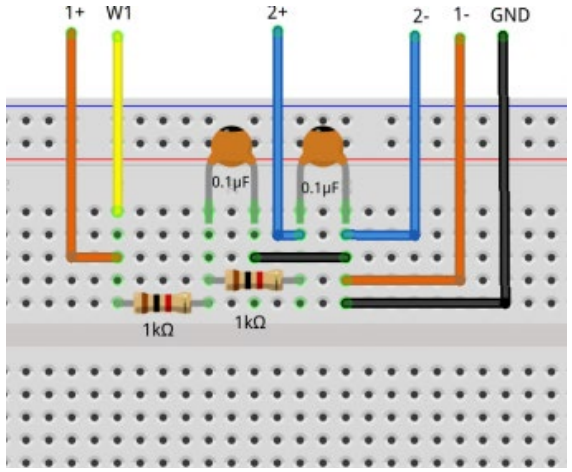
Demo 1

Cascaded Low-pass filters – Transfer Characteristics

Second order Low Pass Filter

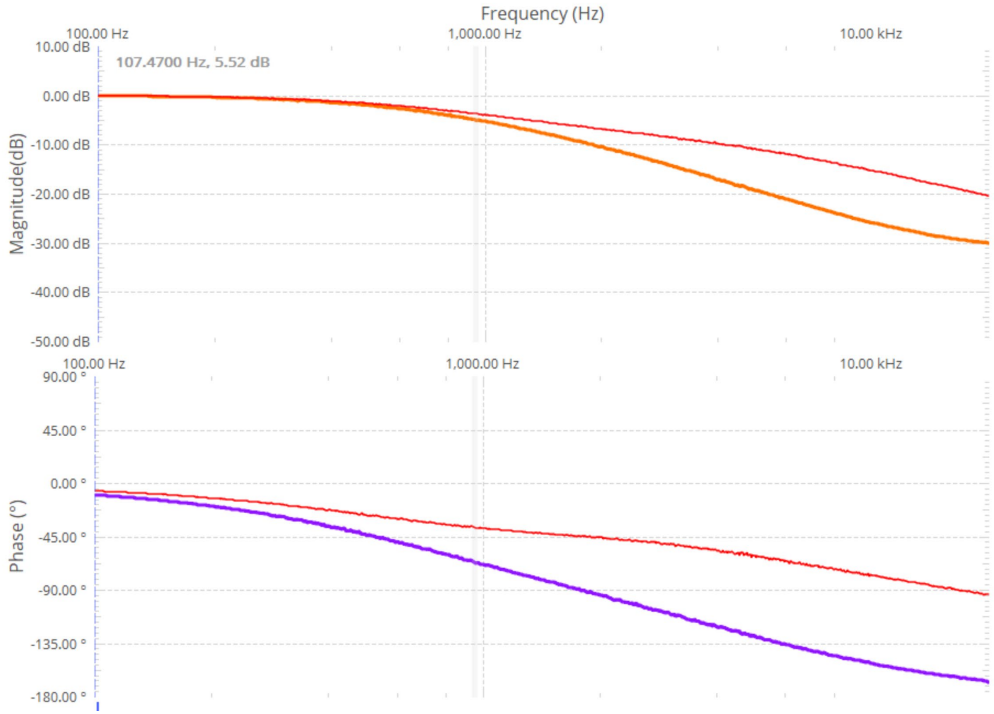
Hardware setup





Procedure:

- Connect the Scope Channel 2 after the first RC group and do a single sweep
- Take a signal snapshot to preserve the result as a reference
- Connect the Scope Channel 2 after the second RC stage and perform another sweep



Hands On Activity

Demo 2

Traffic lights control

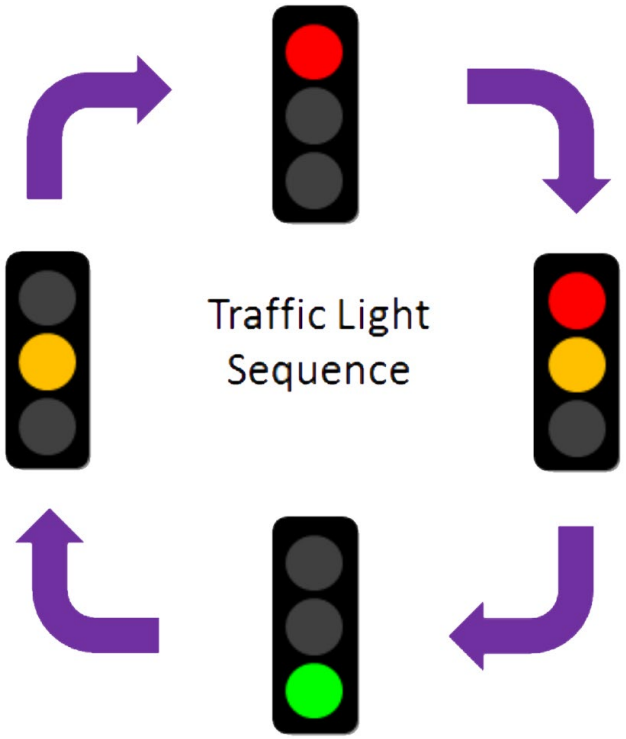
Materials

- ADALM2000 Active Learning Module
- Jumper wires
- 1 SN74HC08N part
- 1 SN74HC32N part
- 1 SN74HC04N part
- 1 Yellow LED
- 1 Red LED
- 1 Green LED

Hands On Activity

Demo 2

Traffic lights control



Flow:

Inputs AB: 00
- **R: ON**
- Y: OFF
- G: OFF

Inputs AB: 01
- **R: ON**
- **Y: ON**
- G: OFF

Inputs AB: 10
- R: OFF
- Y: OFF
- **G: ON**

Inputs AB: 11
- R: OFF
- **Y: ON**
- G: OFF

Hands On Activity

Demo 2

Traffic lights control

Procedure:

- Truth table for the logic function that describes the traffic lights sequence

DIO 0	DIO 1	R	Y	G
0	0	1	0	0
0	1	1	1	0
1	0	0	0	1
1	1	0	1	0

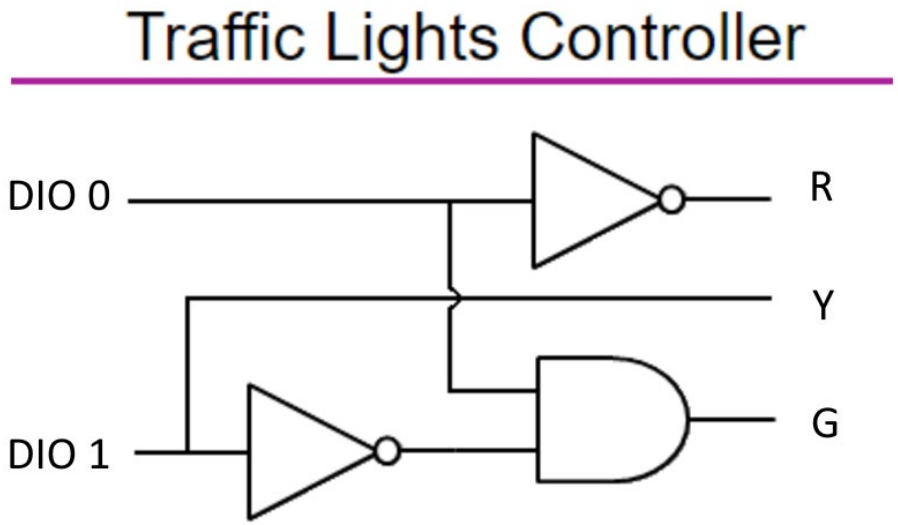
Y = DIO1

R = not(DIO0)

G = DIO0 AND (not(DIO1))

Procedure:

- Logic gates diagram to be implemented in hardware



Hands On Activity

Demo 2

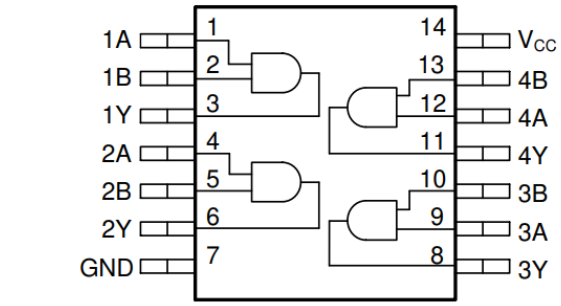
Traffic lights control

Hardware Setup

- Place the ICs on the breadboard with each pin row on one side of the breadboard delimitator
- Open Scopy application
- Open oscilloscope instrument
- Open the power instrument

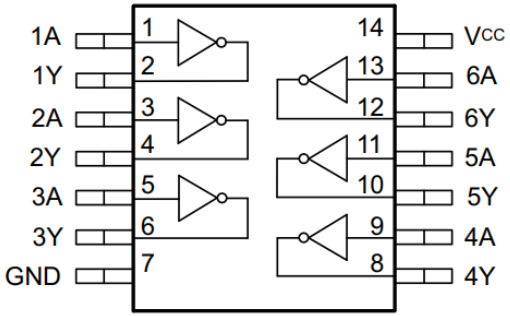
Procedure:

- SN74HC08N Pinout



Functional pinout

- SN74HC04N Pinout



Functional pinout

Hands On Activity

Demo 2

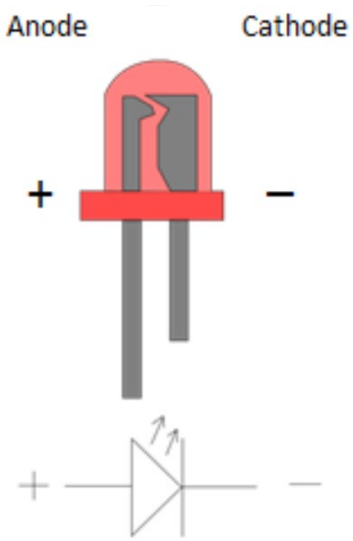
Traffic lights control

Hardware Setup

- Connect the V+ wire to pins 14 of the both ICs - VCC
- Connect GND pin of the M2K to pin 7 of both ICs
- Connect DIO 0 pin to SN74HC04N pin 1
- Connect DIO 0 pin to SN74HC08N pin 1
- Connect DIO 1 pin to SN74HC04N pin 3
- Connect DIO 1 pin to Y LED
- Connect SN74HC04N pin 2 to R LED
- Connect SN74HC04N pin 4 to SN74HC08N pin 2
- Connect SN74HC08N pin 3 to G LED
- Set the V+ to 3.3V and press the Enable button

Procedure:

- LED connection



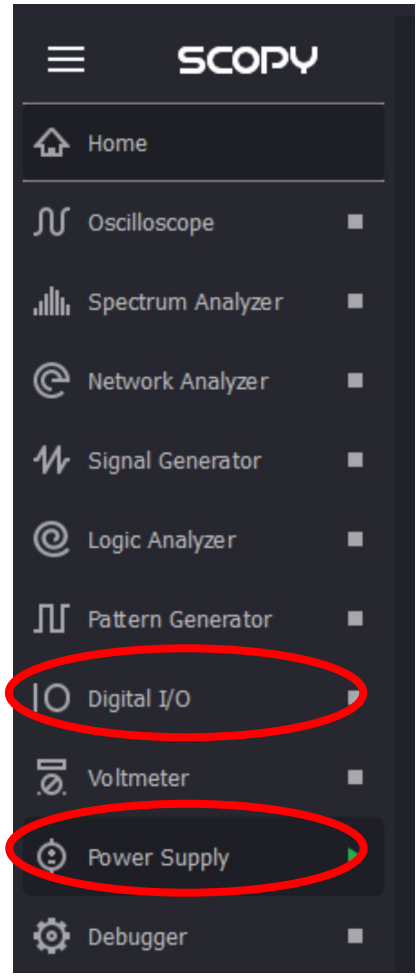
Hands On Activity

Demo 2

Traffic lights control

Hardware Setup

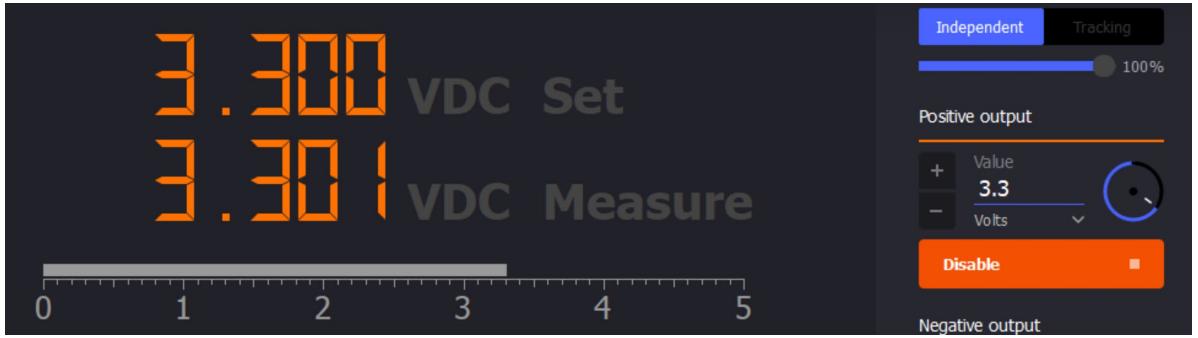
- Open the Scopy Digital IO and Power instruments:
- Toggle the DIO0 and DIO1 digital pins according to the logical function truth table and verify the outputs match the table results



Procedure:

- DIO0 and DIO1 setup

- Power supply setup



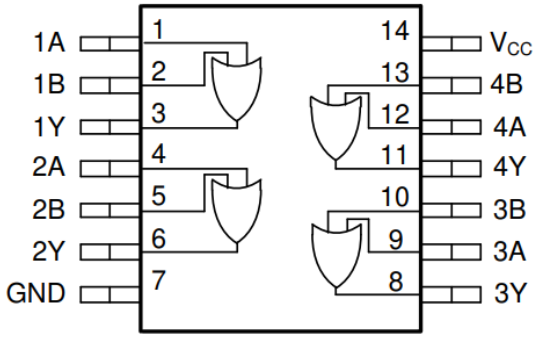
Hands On Activity

Demo 2

Traffic lights control

Challenge:

- Implement a logical OR function using SN74HC32N part from the kit
- Pinout:



Functional pinout

Hands On Activity

Demo 3

NPN Transistor characteristics

Materials

- ADALM2000 Active Learning Module
- Jumper wires
- 1 - 100KΩResistor
- 1 - 100ΩResistor
- 1 - small signal NPN transistor - 2N3904
- 1 - small signal PNP transistor - 2N3906

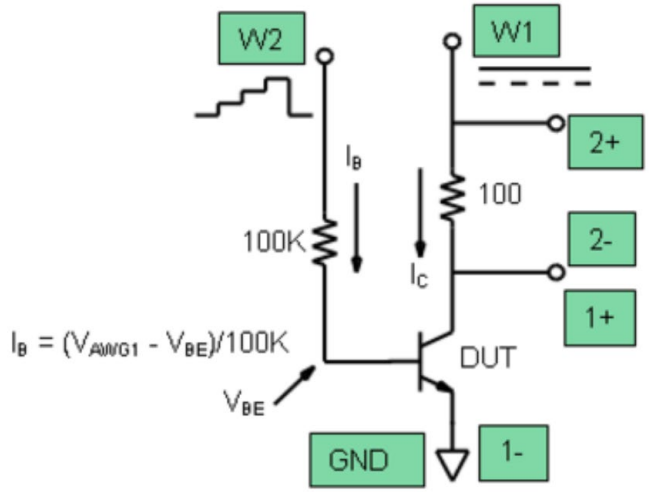
Hands On Activity

Demo 3

NPN Transistor characteristics

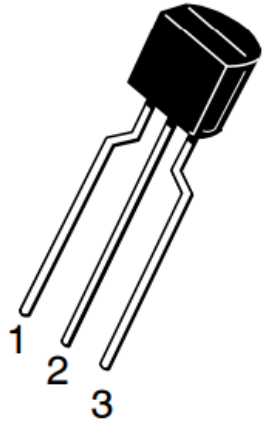
Hardware Setup

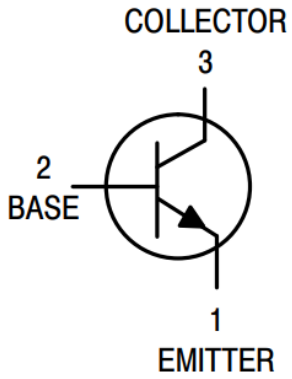
- Place the transistor and resistors on the breadboard
- Make the connections between ADALM2000 and circuit as shown below:



Procedure:

- 2N2904 Pinout





Hands On Activity

Demo 3

NPN Transistor characteristics

Software Setup

- Open Scopy application
- Create a CSV file with a column having values from 0 to 5, save it
- Open the Waveform generator instrument and select Channel 2, load the previously created csv file and make the setup:

Procedure:

- Waveform generator Channel 2 setup

Hands On Activity

Demo 3

NPN Transistor characteristics

Software Setup

- Select Channel 1, make the setup:

Procedure:

- Waveform generator Channel 1 setup

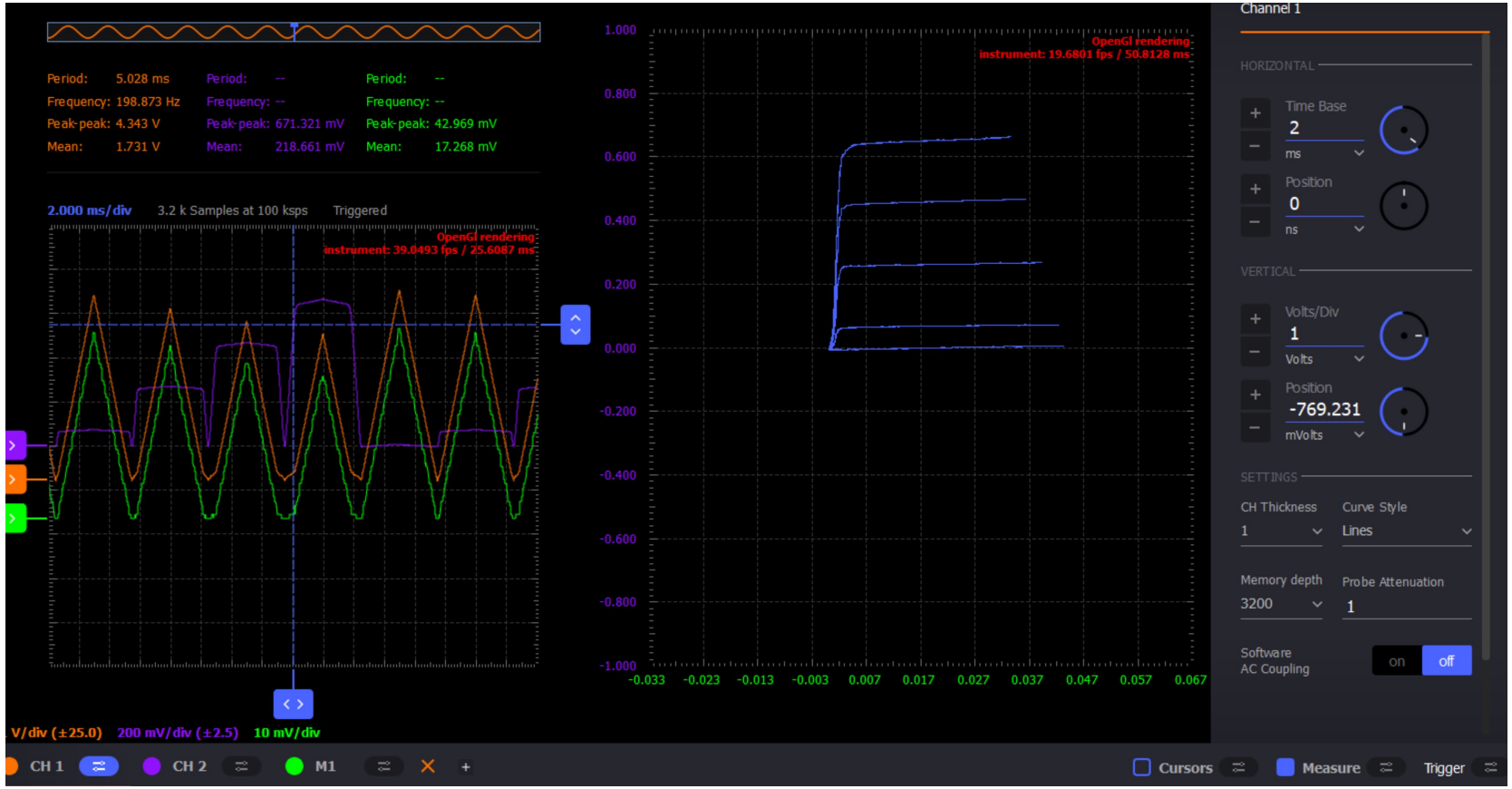
Hands On Activity

Demo 3

NPN Transistor characteristics

Software Setup

- Open the scope and select the XY view
- Add a math channel with the following function: M1 = t0/100 – represents the Ic current, given the 100 ohms collector resistor
- Observe the out characteristics of the NPN transistor Ic = f(Vce)



Hands On Activity

Demo 3

NPN Transistor characteristics

Challenge

- Obtain the characteristics for a PNP transistor provided
- The curve trace should look like the one in the image

Hands On Activity

Demo 3

NPN Transistor characteristics

Challenge

- Obtain the characteristics for a PNP transistor provided

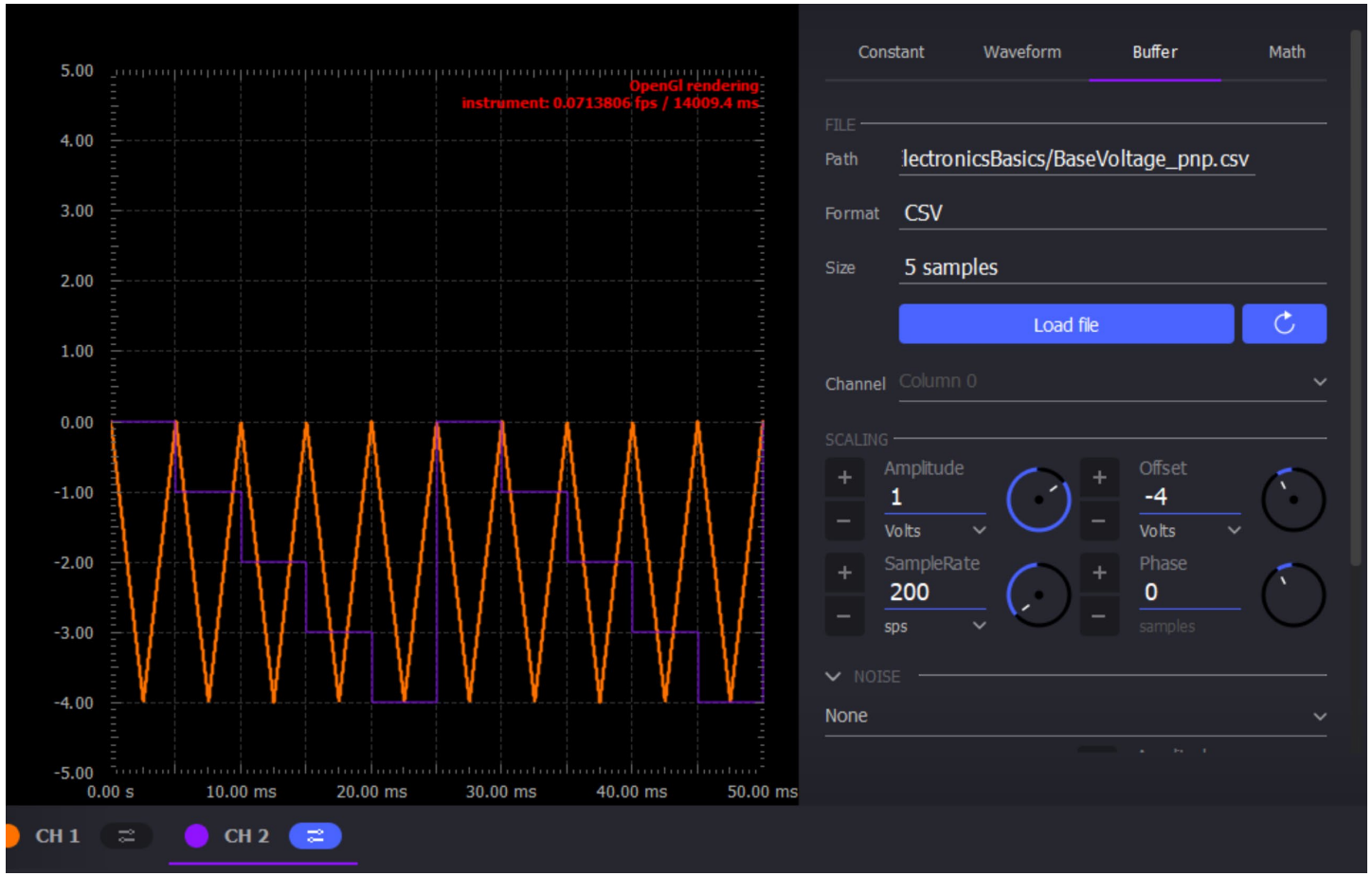
Hands On Activity

Demo 3

NPN Transistor characteristics

Challenge

- Obtain the characteristics for a PNP transistor provided



Hands On Activity

Instructor-led activity
Homemade Battery – LED control

- Materials:
  - ADALM2000 Active Learning Module
  - Jumper wires (wires with alligator clips will work best)
  - 3 lemons: large, fresh, “juicy” lemons work best.
  - Zinc plated screws or nails
  - Copper plated coins or copper nails or heavy gauge (14 or 12) copper wire.
  - Red LED

http://www.iconarchive.com/show/noto-emoji-objects-icons-by-google/62807-radio-icon.html
http://www.streamlineicons.com
http://pixelkit.com

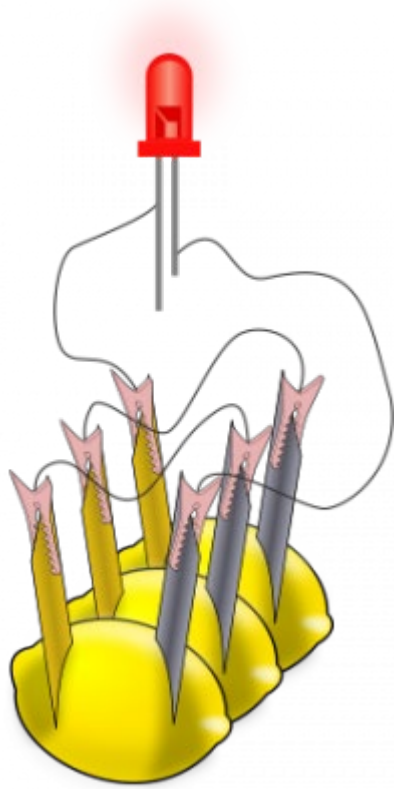
Hands On Activity

Instructor led

LED control using a homemade Battery

Hardware setup

- Insert a copper penny into a small cut or push a copper nail or heavy gauge wire into one side of the lemon.
- Push a galvanized (zinc coated) screw or nail into the other side of the lemon. The zinc and copper electrodes must not touch.



Procedure:

- Open Scopy application
- Open oscilloscope instrument
- Measure the voltage of your single cell using one of the ADALM2000 input channels
- Observe if the red LED lits when the parts are connected and draw conclusions

Resources

- https://wiki.analog.com/university
- https://wiki.analog.com/university/courses/alm1k/intro/real-voltage-sources
- https://wiki.analog.com/university/courses/electronics/electronics-lab-4
- https://wiki.analog.com/university/courses/engineering_discovery/lab_13
- Specific hardware resources:
- https://www.britannica.com/technology/integrated-circuit/Photolithography
- https://learn.sparkfun.com/tutorials/transistors/all

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