Embedded System Design Techniques™

Building Your Own Internet Connected PLC

Class 2: Designing a PLC

April 23rd , 2018
Jacob Beningo

Course Overview

Topics:

- PLC Fundamentals
- **Designing a PLC**
- PLC Software Design Part 1
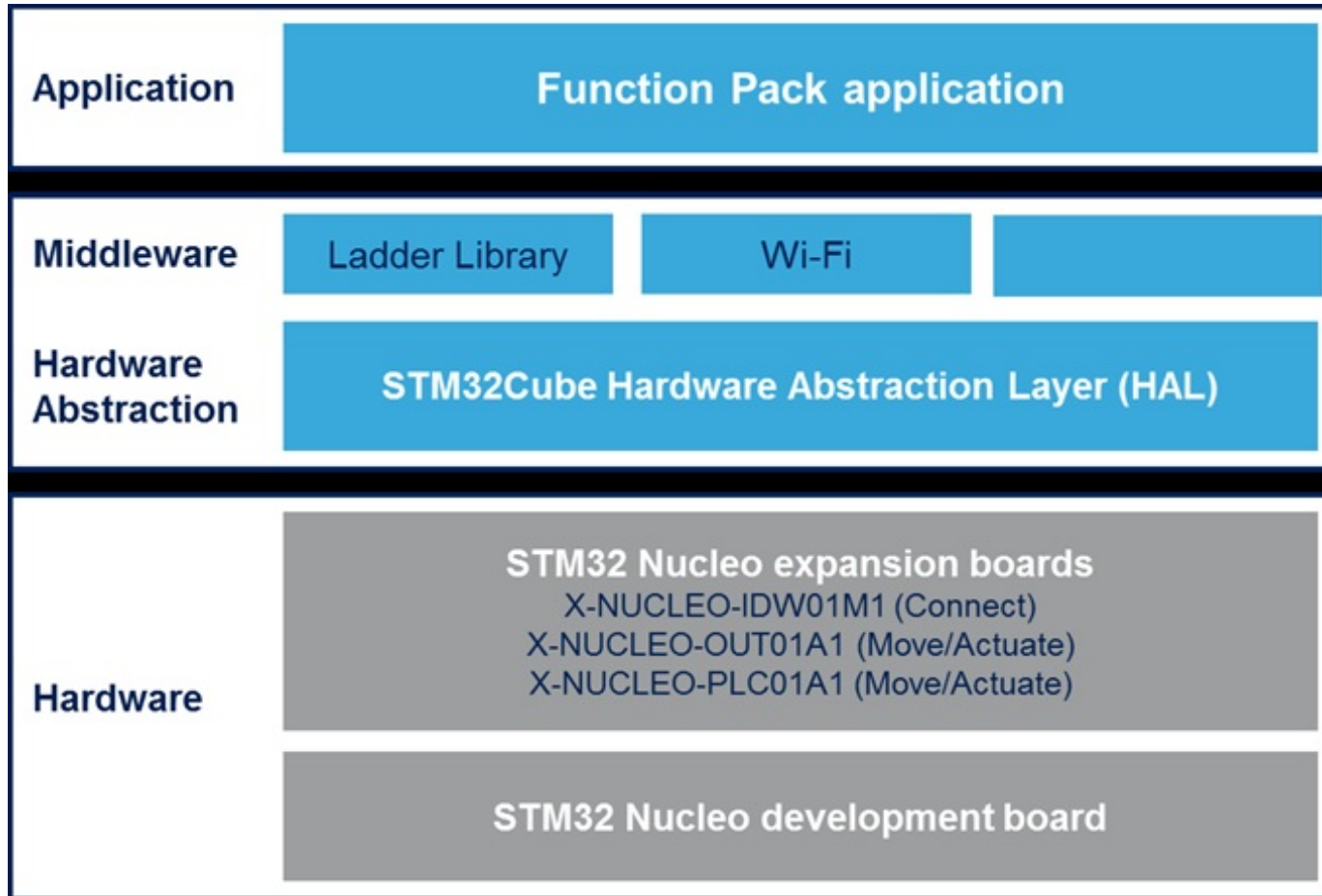- PLC Software Design Part 2
- PLC Application Design

Presented by:

DesignNews

CEC CONTINUING EDUCATION CENTER

Digi-Key ELECTRONICS

Session Overview

- Wireless PLC Overview

- STM32 Wireless PLC

- Application Hardware

- KT Matrix

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Wireless PLC Overview

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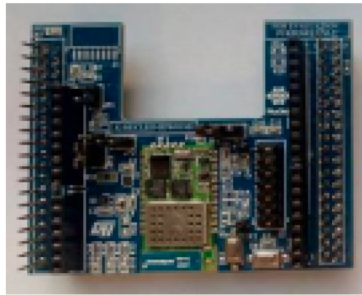
What You will need ...
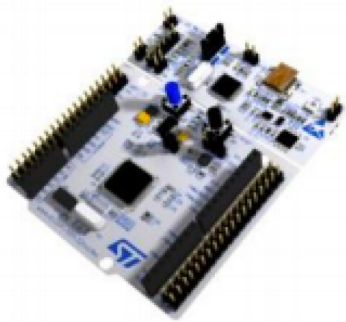
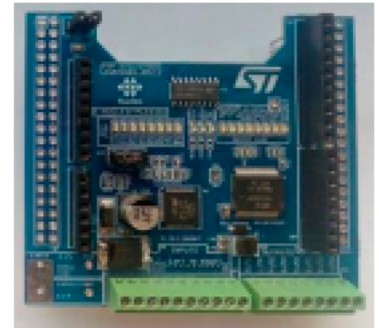Nucleo-401RE   X-Nucelo-IDW01M01   X-Nucelo-PLC01A1

X-Nucleo-OUT01A1   Power Supply   A light snack ...

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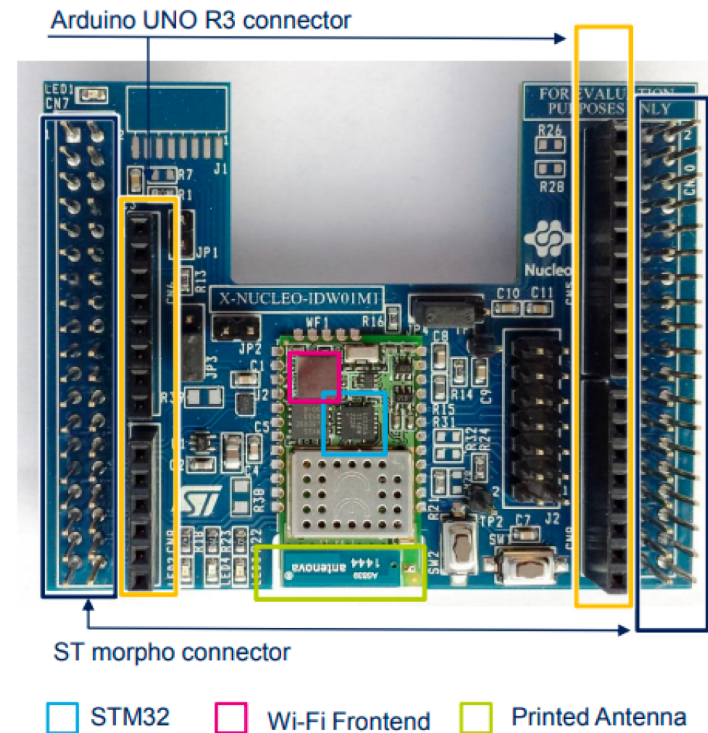
STM32 Hardware Overview

X-NUCLEO-IDW01M1

- Wi-Fi Module
- FCC, IC, CE Certified
- Arduino UNO R3 headers
- 802.11 b/g/n compliant
- Integrated antenna

Arduino UNO R3 connector

X-NUCLEO-IDW01M1

ST morpho connector

☐ STM32   ☐ Wi-Fi Frontend   ☐ Printed Antenna

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STM32 Hardware Overview

X-NUCLEO-OUT01A1

- Solid State Relays
- 10.5 to 33 V Operating Voltage
- High Side Solid State Relay (ISO9200BQ)
- Channel Output 0.7 amps
- Status LED's
  - Thermal protection
  - Communication fault
- Output Status Indicator
- Reverse protection diodes
- Galvanic insulated outputs

ISO8200BQ

Protection Diodes
SMC30J30CA – STPS1H100A

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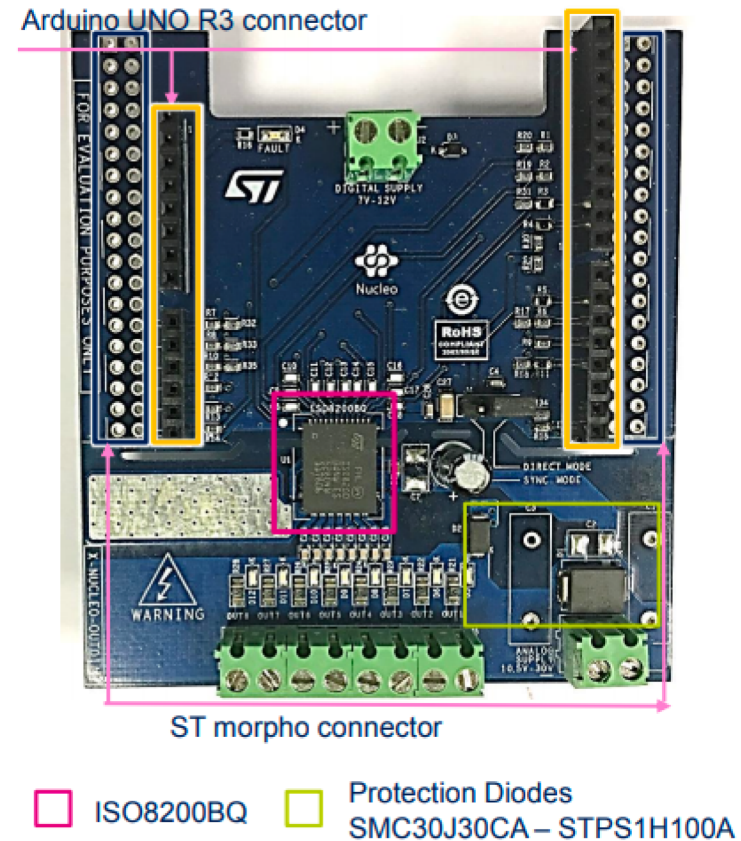
STM32 Hardware Overview

X-NUCLEO-PLC01A1

- Industrial Input / Output
- 8 Inputs (CLT01-38SQ7)
- 8 Outputs (VNI8200XP)
- SPI Link Communication
- Arduino headers

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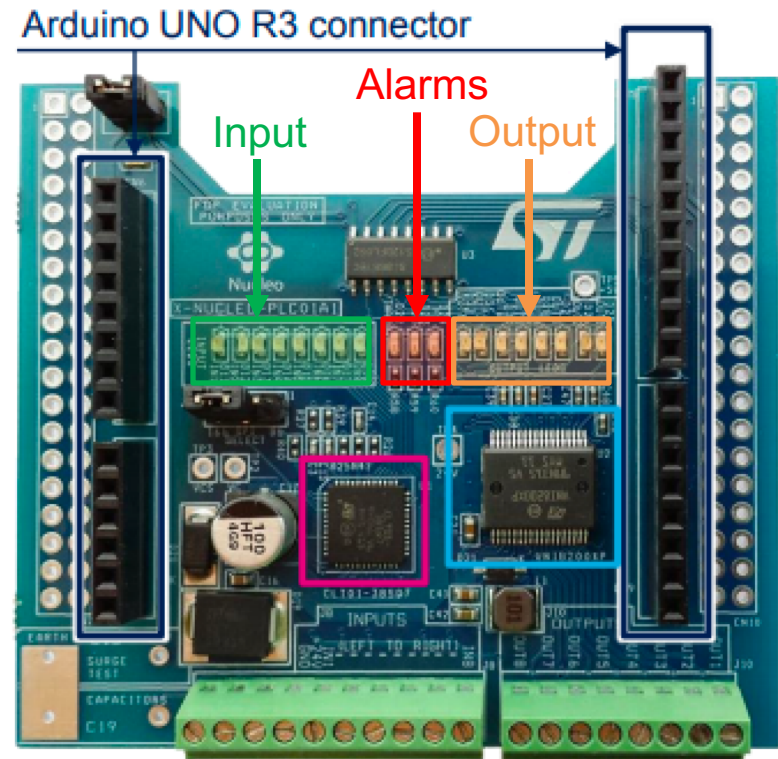
STM32 Hardware Overview

Nucleo-401RE

- ARM® Cortex®-M4 84 MHz
- 512 KB Flash
- 96 KB RAM
- ST-Link Programmer
- Arduino headers

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Hardware Setup

X-NUCLEO-OUT01A1
(Output)

X-NUCLEO-PLC01A1
(PLC)

X-NUCLEO-IDW01M1
(Wireless)

Nucleo-401RE
(MCU)

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Hardware Setup

Digital Supply

Analog Supply

Mode

12.0 V

12.0 V

Choose Your
Own Adventure

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Hardware Setup

Outputs

Indicators

Output

Alarms

Input

Inputs

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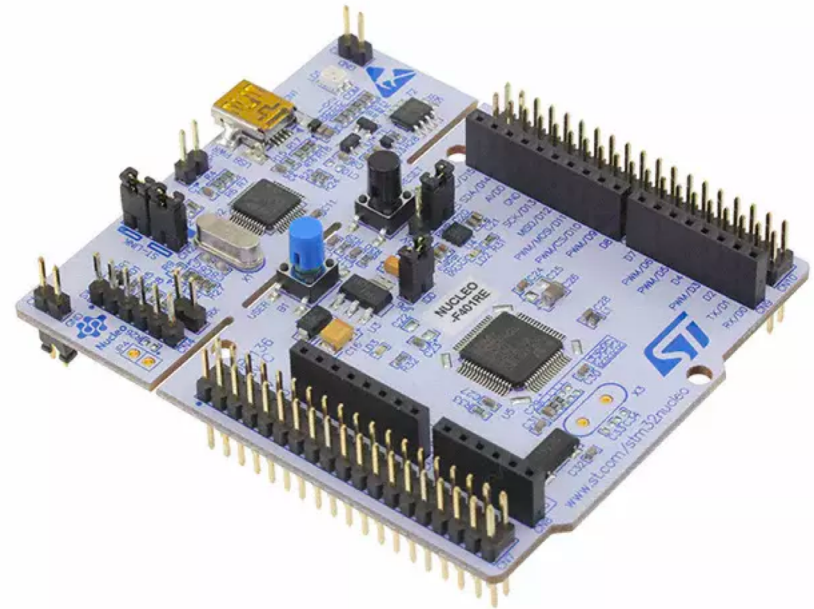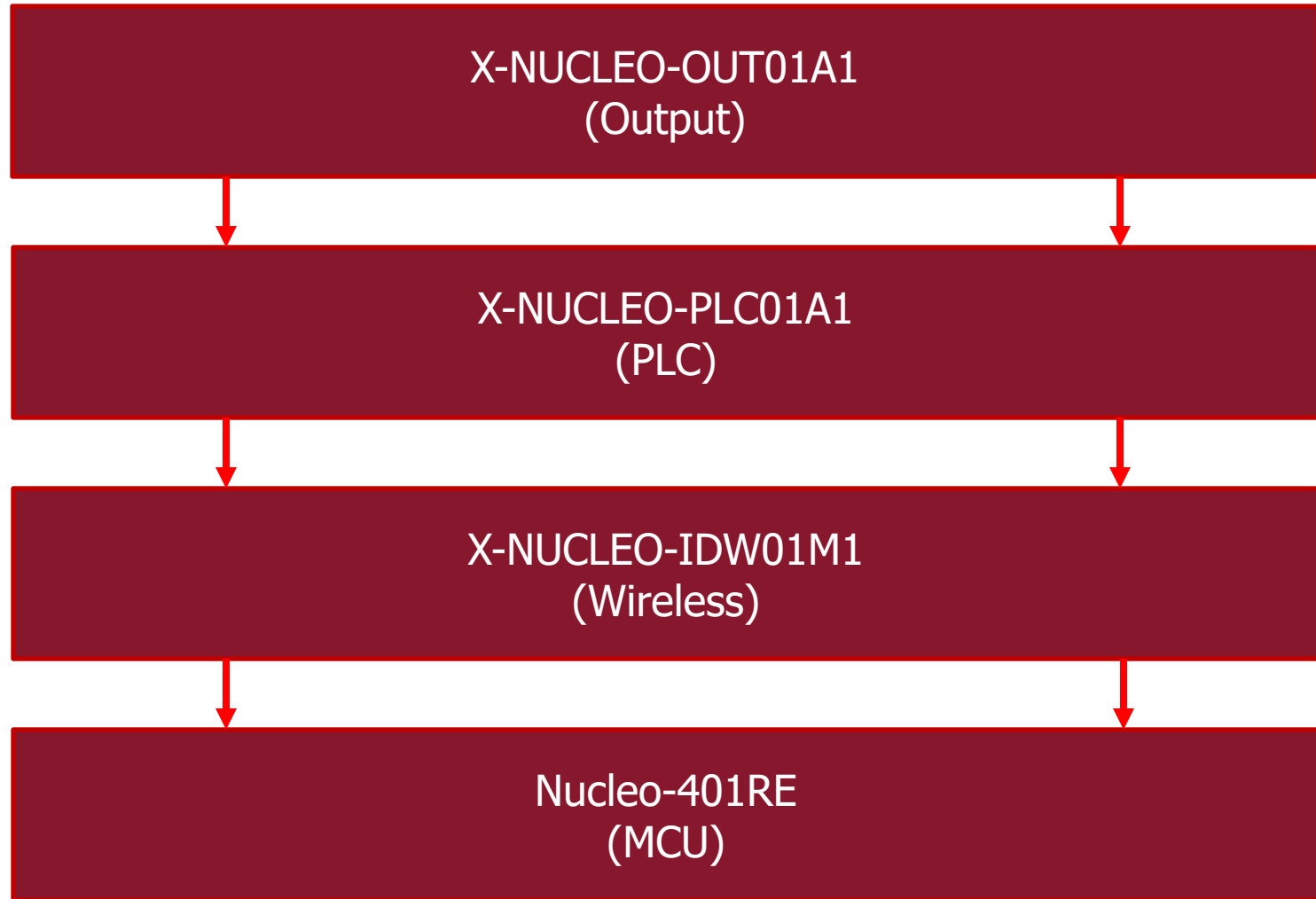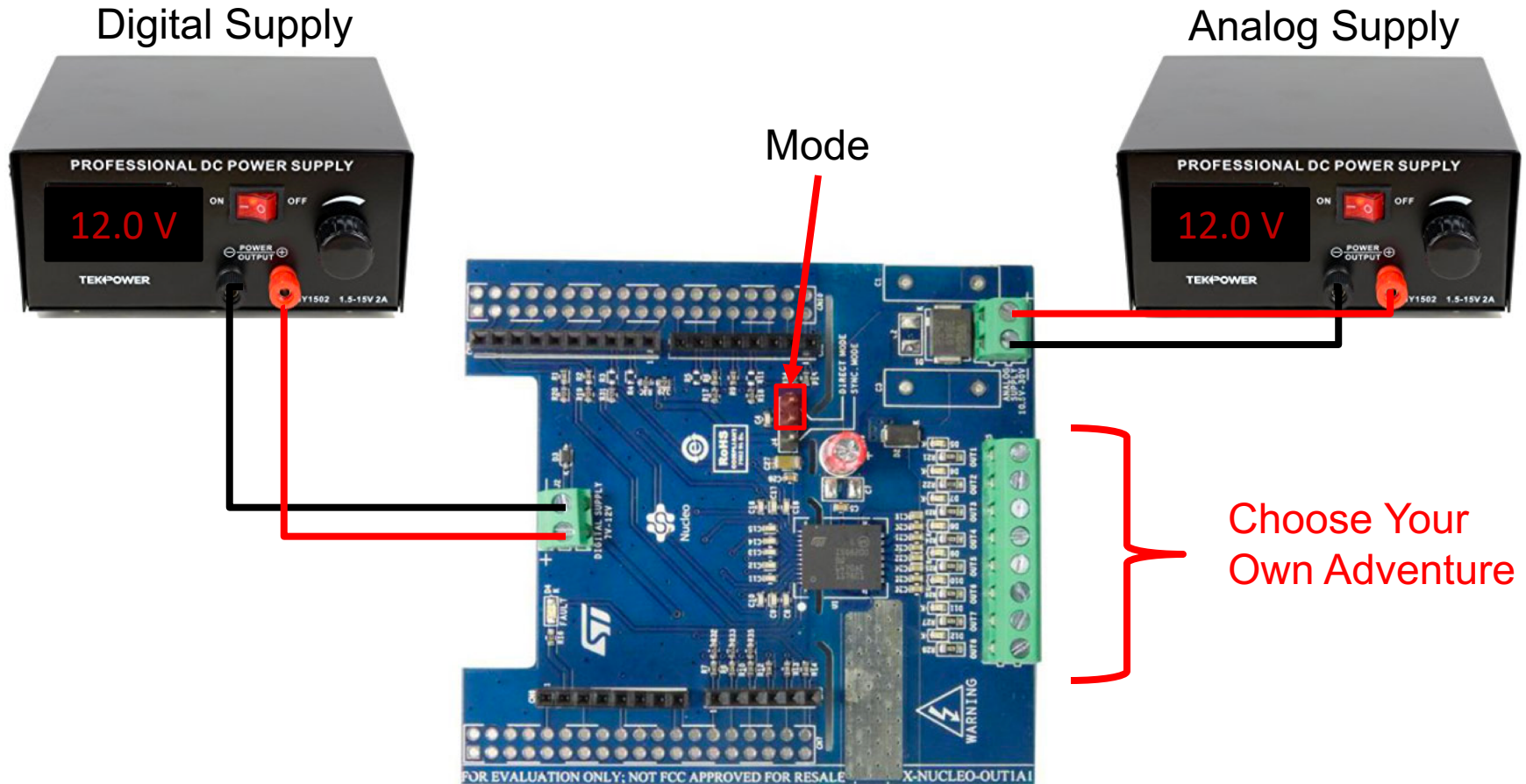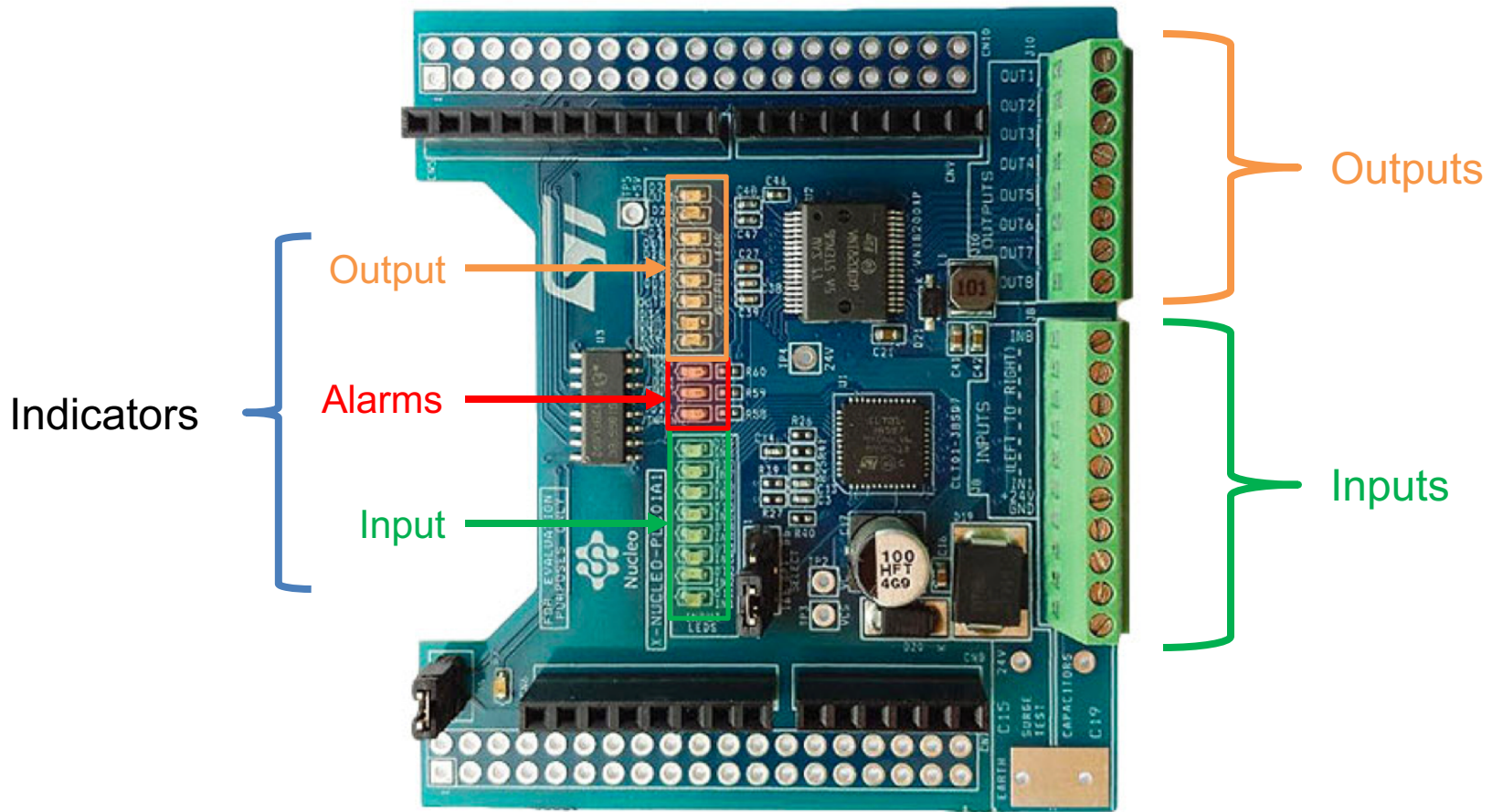
Application Hardware Selection

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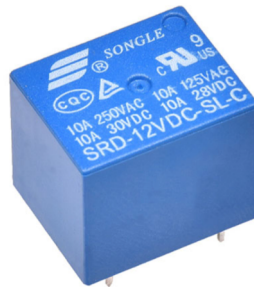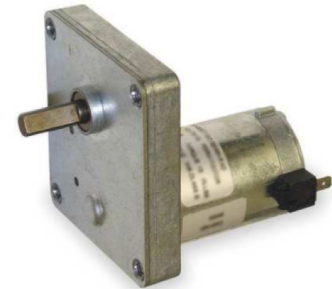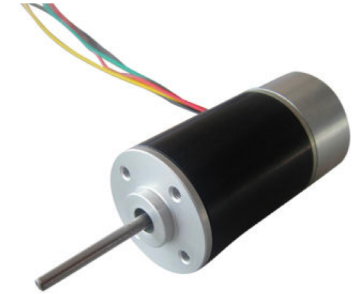
The KT Matrix

Kepner-Tregoe (KT) Decision Matrix

- A decision making technique that uses a decision matrix to force a ranking among possible alternative solutions

- Can be used to solve a problem and gain group consensus

- Arrive at a numeric number that can be compared

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The KT Matrix

9 Step Procedure to Evaluate Solutions

1)   State the issue, problem, and decision to be made.
2)   Explain the use of the decision matrix technique to participants.
3)   Draft a matrix on a flip chart or white board with candidate choices positioned as rows and criteria as columns.
4)   Weigh the criteria, if required (e.g., 1-5 weight).
5)   Rate each choice within each decision/selection criteria (e.g, 1-5 score - do not rank here).
6)   Multiply the rating by its relative weight to determine weighted score.
7)   Total the scores.
8)   Review results and evaluate, using common sense and good judgment.
9)   Reach consensus.

The KT Matrix

1) Select an appropriate RTOS for a project

2) KT Matrix will evaluate how well each RTOS meets our project requirements

3) Major RTOS Concerns:

- Performance, Features, Cost, Ecosystem, Middleware, Vendor, Engineer, Security

- Identify specific criteria such as:

  - RAM and ROM Usage

  - Support, etc

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The KT Matrix

4) Select an appropriate RTOS for a project

1) KT Matrix will evaluate how well each RTOS meets our project requirements

2) Major RTOS Concerns:

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- Identify specific criteria such as:

  - RAM and ROM Usage

  - Support, etc

The KT Matrix

5) Develop the ranking criteria

Weighting System		
1	Could care less but still should consider	
2	Probably don't need	
3	Nice to have but not mission critical	
4	Not critical but must have	
5	Critical must have	

The KT Matrix

6 - 8) Rank and evaluate the matrix

	Criteria	Weight	RTOS #1						RTOS #2						RTOS #3					
			Rating 1	Rating 2	Rating 3	Rating 4	Rating 5	Weighted Rating Total	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5	Weighted Rating Total	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5	Weighted Rating Total
Performance	Smallest RAM footprint	4	3	3	3	3	3	60	2	2	2	2	2	40	1	1	1	1	1	20
	Smallest ROM footprint	4	2	2	2	2	2	40	1	1	1	1	1	20	3	3	3	3	3	60
	Highest degree of determinism	5	2	1	1	1	2	35	1	2	2	2	1	40	3	3	3	3	3	75
	Best meets reliability requirements	5	1	2	2	1	1	35	3	1	1	3	2	50	2	3	3	2	3	65
	Minimal context switch times	5	1	1	1	1	1	25	2	2	2	2	2	50	3	3	3	3	3	75
	Minimal interrupt latency	5	1	2	1	1	1	30	2	3	3	3	3	70	3	1	2	2	2	50
	Lowest energy consumption	4	3	3	3	3	3	60	2	2	2	2	2	40	1	1	1	1	1	20
Features	Best Real-time trace capabilities	3	2	1	2	3	1	27	1	2	3	1	2	27	3	3	1	2	3	36
	Supports static allocation of RTOS objects	4	3	3	3	3	3	60	2	2	2	2	2	40	1	1	1	1	1	20
	Most efficient memory protection	4	2	3	1	2	3	44	3	1	2	3	1	40	1	2	3	1	2	36
	Easiest to scale	5	3	2	3	2	3	65	1	3	1	3	1	45	2	1	2	1	2	40
	Easiest to configure features	5	2	2	3	1	1	45	1	1	2	2	2	40	3	3	1	3	3	65
	Processor derivative fully supported	5	2	2	2	2	2	50	1	1	1	1	1	25	3	3	3	3	3	75
	Conforms to required interface standards (i.e. POSIX, DO-178B)	3	1	1	1	1	1	15	3	3	3	3	3	45	2	2	2	2	2	30
	Easiest to port to other MCU's and architectures	3	1	2	3	1	2	27	2	3	1	2	3	33	3	1	2	3	1	30
	Most relevent safety certifications	4	3	2	3	1	3	52	2	3	1	3	1	40	1	1	2	1	2	28
Cost	Lowest upfront licensing costs	5	3	3	3	3	3	75	1	1	1	1	1	25	2	2	2	2	2	50
	Lowest royalty cost per unit	3	3	3	3	3	3	45	2	2	2	2	2	30	1	1	1	1	1	15
	Greatest familiarity with this RTOS	4	3	2	1	1	2	36	1	3	2	2	3	44	2	1	3	3	1	40
	Lowest time to get up to speed with RTOS specifics	3	1	2	3	3	2	33	2	3	1	1	3	30	3	1	2	2	1	27
	Smallest tool investment	4	3	2	2	3	3	52	1	3	3	1	1	36	2	1	1	2	2	32
	Lowest training investment	5	2	1	3	2	1	45	1	3	2	1	3	50	3	2	1	3	1	50
	Lowest cost of middleware (price and integration effort vs quality	5	2	1	2	2	2	45	3	2	3	3	1	60	1	3	1	1	3	45
	Least open source (minimize new IP release)	3	1	1	1	1	1	15	2	3	3	2	2	36	3	2	2	3	3	39
EcoSystem	Highest adoption rate in target industry	3	3	2	3	2	3	39	1	3	1	3	2	30	2	1	2	1	1	21
	Most architectures supported	3	2	2	2	2	2	30	3	3	3	3	3	45	1	1	1	1	1	15
	Largest and most vibrant forum community (fast to respond)	4	2	3	2	3	1	44	1	2	1	1	3	32	3	1	3	3	2	48
	Fastest technical support available	5	1	2	1	2	1	35	2	3	2	3	2	60	3	1	3	1	3	55
	Highest quality professional training available	2	2	1	2	1	2	16	1	3	1	3	1	18	3	2	3	2	3	26
	Example projects and source available	4	2	3	2	3	2	48	3	1	3	1	3	44	1	2	1	2	1	28
	Integrated development tools and plugins	4	2	1	3	2	1	36	1	3	1	1	3	36	3	1	3	3	1	44

Presented by:

The KT Matrix

6 - 8) Rank and evaluate the matrix

	Criteria	Weight	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5	Weighted Rating Total	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5	Weighted Rating Total	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5	Weighted Rating Total
Middleware	File system best meets system requirements	4	2	1	2	2	1	32	3	2	3	3	1	48	1	3	1	1	3	36
	TCP/IP stack best meets system requirements	4	2	1	2	2	1	32	3	2	3	3	1	48	1	3	1	1	3	36
	USB stack best meets system requirements	4	2	1	2	2	1	32	3	2	3	3	1	48	1	3	1	1	3	36
	Graphics stack best meets system requirements	4	2	1	2	2	1	32	3	2	3	3	1	48	1	3	1	1	3	36
	Middleware requires minimal integration effort	4	2	1	2	2	1	32	3	2	3	3	1	48	1	3	1	1	3	36
	Additional 3rd party tools integrated seamlessly	3	1	2	1	2	1	21	2	3	2	3	2	36	3	1	3	1	3	33
Vendor	Best historical track record	3	2	2	1	3	1	27	3	3	2	1	2	33	1	1	3	2	3	30
	Most relevent certified development process	3	1	1	2	1	1	18	2	2	3	2	2	33	3	3	1	3	3	39
	Shortest support request times	5	1	1	2	2	2	35	2	2	2	3	3	60	3	3	3	1	1	55
	Best strategic fit	4	2	2	1	2	2	36	1	1	2	3	3	40	3	3	3	1	1	44
	Longest term support for the RTOS	4	2	2	1	1	2	32	3	3	2	2	3	52	1	1	3	3	1	36
	Best code quality	4	1	1	2	2	1	28	2	2	3	3	2	48	3	3	1	1	2	40
	Best code documentation	4	2	2	1	2	2	36	3	3	2	3	3	56	1	1	3	1	1	28
Engineer	Minimal professional growth potential	2	2	2	1	3	1	18	1	1	3	2	3	20	3	3	1	1	2	20
	Least amount of stress to implement	2	2	3	1	1	3	20	1	2	3	3	2	22	3	1	2	2	1	18
	Most fun / interesting	1	2	3	3	1	2	11	3	1	1	2	3	10	1	2	2	3	1	9
	Minimized labor intensity	3	1	2	3	1	3	30	2	3	1	2	1	27	3	1	2	3	2	33
	Least deadline constrained to get up to speed	2	2	1	2	1	3	18	3	2	3	2	1	22	1	3	1	3	2	20
	Most internal resources available	3	1	2	3	3	3	36	2	3	1	1	1	24	3	1	2	2	2	30
	Total	188	96	92	100	97	93	1790	99	111	103	110	98	1944	105	96	97	94	101	1875
					RTOS #1						RTOS #2						RTOS #3			

9) Come to a consensus

Additional Resources

- Download Course Material for
  - C/C++ Doxygen Templates
  - Example source code
  - Blog
  - YouTube Videos
- Embedded Bytes Newsletter
  - http://bit.ly/1BAHYXm

From www.beningo.com under

- Blog > CEC – Building Your own Internet Connected PLC