



Course Overview:

Embedded systems are becoming complex and even resource constrained devices are requiring a Real-Time Operating System (RTOS). In this workshop, attendees will be walked through RTOS fundamentals starting with simple bare-metal scheduling techniques through the intricacy required to design a RTOS based application. Attendees will examine practical examples and techniques that will decrease their learning curve and help them avoid the common pitfalls many developers fall into when starting to use an RTOS. This course will also leverage Percepio's Tracealyzer to further enhance attendees RTOS application understanding.

Who Should Attend?

Attendees are engineers who are interested in or will be designing applications using a Real-time Operating System. The course covers the fundamentals that are rarely discussed in courses or online literature, making the course immediately applicable to the real world. The course is appropriate for engineers with little experience in the area or experienced engineers looking for new techniques and skills. Attendees should understand the fundamentals of the C programming language. Advanced concepts are reviewed as they apply.

Key Take-a-ways:

- Hands-on experience developing RTOS based applications
- How to develop your own real-time scheduler
- The steps necessary to decompose an application into tasks
- Analysis techniques for setting task priorities
- Developing a software architecture
- How to synchronize tasks with semaphores, mutexes and more
- Memory management strategies for real-time systems
- Example code and test hardware platform
- Key concepts related to robustness and efficiency
- Troubleshooting and debugging techniques
- Best practices for RTOS based applications

Course Format:

This course is offered live online, as a self-paced course. Public and on-site courses are available on request.

Cost:

Single Regular: \$1000 USD
Group Rates: Contact jacob@beningo.com

Contact Information:



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Sessions Overview:

Session 1 – Real-time Embedded Systems Concepts

- Hard versus soft real-time
- Bare metal scheduling techniques
- Designing a Cooperative Scheduler
- Best practices

Session 2 – Real-time Operating Systems

- RTOS Characteristics
- Baremetal versus RTOS
- Real-time Kernels Overview
- Preemptive scheduling
- RTOS terminology
- Selecting the right RTOS
- Setting up an RTOS
- Tools overview
- Best Practices

Session 3 – Managing Tasks and Threads Part 1

- Introduction to tasks
- Task versus Thread
- Handling Critical sections

- Reentrant functions
- Task Control Blocks
- Preemption and context switches
- Creating tasks
- Identifying and partitioning tasks
- RTOS Application software architecture

Session 4 – Managing Tasks and Threads Part 2

- Setting task priorities using rate monotonic analysis (RMA)
- RTOS based Round Robin scheduling
- Time slicing
- Stack sizing and issues
 - Stack overflow detection
 - Worst case stack analysis techniques
- Best Practices

Session 5 – Task Synchronization Fundamentals Part 1

- Task Synchronization and Coordination
- Semaphores
- Binary versus counting
- Mutexes
- Synchronizing from ISRs
- Semaphores versus mutexes
- Best Practices

Session 6 – Task Synchronization Fundamentals Part 1

- Message Queues
- Event Flags
- Selecting the right synchronization
- Best Practices

Session 7 – Managing Memory

- Singly linked lists
- Doubly linked lists
- Dynamic versus static memory
- Understanding the heap and Malloc
- Memory byte pools
- Memory block pools
- Memory Management Strategies
- Best Practices

Note: Each lecture has an associated lab.

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Frequently Asked Questions (FAQ):

How long do I have access to the course materials for?

Attendees have access to the materials indefinitely. Attendees not only get to keep the materials and recordings but may also attend any online live runs of the class at any point in the future and will also get access to any updates to the course.

What hardware and toolchain does the course use?

Amazon FreeRTOS is supported by several different silicon vendors and the list is growing every day. The course is designed to work with any of these boards. You choose your board at:

<https://aws.amazon.com/freertos/getting-started/>

You can then order the board from your favorite electronics distributor.

What format is the course offered in?

The courses are offered in three different formats:

- Live Online w/ access to recording (self-paced materials)
- Self-paced online
- Public
- *Company* On-site courses

Is there a discount for multiple people to attend?

Yes. There is a discount for 3+ attendees. Please contact us for details.

How are the online live sessions hosted?

Live sessions are hosted through GoTo Webinar. After sign-up, you will receive the link to registered for the online sessions about a week before they start. If you miss an online session, the recording is usually posted to the course site within 24 hours.

How do I access the course materials?

Course materials are hosted at <https://beningo.mykajabi.com/library>. After ordering, you will receive a username and login to access the materials.

If I attend a live course, do I still get access to the online course?

Yes. If you attend a course live online or in person, you will get access to the self-paced recordings and materials that you can then reference and access at a later date.

Lecturer Background



Jacob Beningo is a Certified Software Development Professional (CSDP), chair of the IEEE South Eastern Michigan Consultants Affinity Group, an independent consultant and lecturer who specializes in the design of embedded software for resource constrained and low energy mobile devices. He has successfully completed projects across a number of industries including automotive, defense, medical and space. He enjoys developing and teaching real-time and reusable software development techniques using the latest methods and tools. He blogs for EDN.com about embedded system design techniques and challenges. Jacob holds *bachelor's* degrees in Electrical Engineering, Physics and Mathematics from

Central Michigan University and a Master's degree in Space Systems Engineering from the University of Michigan.

Additional resources, templates and Jacob's monthly embedded software newsletter can be found at www.beningo.com . Check out his other workshops at <http://www.beningo.com/services/workshops/>

Click the social media link below to follow Jacob and get more tips and tricks:



Blogs can be found at the following sites by clicking the image:



Testimonials

“I would like to express my gratitude to Mr. Beningo for putting together this bootloader class. His excellent teaching skills made the training very enjoyable. The videos and material provided, including the laboratories, contributed to my success in understanding that topic. It was also very comforting to know that whenever I had a question he was always available. I cannot wait to put this knowledge into practice! I recommend this class to anyone serious about embedded system design and engineering.”

-- Michel Bédard

“Thank you for the extra materials and the course – I now understand better some issues specific for embedded systems, I also learned few things I didn’t know yet. It definitely influences my performance in daily work (IP and its driver prototyping in embedded system) and already allowed me to successfully debug some strange behavior”

-- Arek Golec

“In addition to having an extremely high level of expertise with regard to architecting and implementing embedded software and real-time embedded systems, Jacob has a rare talent for communication. His cheerful disposition, enthusiasm, and depth of knowledge make Jacob one of the most popular presenters at the [Embedded Systems Conference \(ESC\)](#). Jacob's sessions are always well-attended (often standing room only) and well-received by the attendees.”

-- Clive "Max" Maxfield, Editorial Director, Embedded.com, and Technical Content Director, ESC

“Jacob Beningo conducted a 5-session hands-on class on the fundamentals of microcontrollers for EETimes University, that was sponsored by STMicroelectronics. While the “fundamentals” approach was familiar, we added the unique hands-on wrinkle and Jacob proved to be an excellent instructor. He adapted seminar material we supplied and patiently walked the on-line class through lessons while contributed to their learning about the valuable features of the provided STM32 microcontroller and Discovery Kit. His success in leading the class was amply demonstrated in the outstanding participant engagement during the sessions and in their comments and feedback afterwards.”

-- Michael Markowitz, Director Technical Media Relations, STMicroelectronics