

ESP8266 Workshop I

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Workshop overview

- ESP8266 introduction: hardware and software
- ESP-01 and ESP-12 set-up for development
- Flashing firmware using esptool
- NodeMCU and Lua introduction
- ESPlorer IDE
- Using a button and LED(s)
- Setting up as a Wi-Fi client
- Using UDP to send and receive messages
- Creating an MQTT client

ESP8266 Hardware

- 3.3V device, operating current ~ 215 mA
- CPU: Tensilca Xtensa LX3: 32-bit, 72 MHz (?)
- ESP8266 SOC: Expressif
- RAM 32Kb, DRAM 80Kb, Flash 200Kb (for SDK)
- Wi-Fi 802.11 b/g/n 2.4 GHz radio (station or AP)
- Timers, deep sleep mode, JTAG debugging
- Peripherals ...
 - GPIO (upto 16), PWM (3), ADC (one)
 - UART, I2C, SPI

ESP8266 Memory Map

- More complicated than your AVR ATmega / Arduino
- SRAM 32Kb
 - NodeMCU heap memory available: `print(node.heap())`
- SPI Flash ROM layout: Since SDK 0.8 ...

| | | | | |
|---|--------|------|---------------------------|--|
| • | 00000h | 248k | app.v6.flash.bin | User application |
| | 3E000h | 8k | master_device_key.bin | OTA device key |
| | 40000h | 240k | app.v6.irom0text.bin | SDK libraries |
| | 7C000h | 8k | esp_init_data_default.bin | Default configuration |
| | 7E000h | 8k | blank.bin | Filled with FFh. May be WiFi configuration |
- <https://github.com/esp8266/esp8266-wiki/wiki/Memory-Map>

ESP8266 Software stack

- Can build using FreeRTOS: <http://www.freertos.org>
 - https://github.com/espressif/esp_iot_rtos_sdk
- ESP8266 SDK: hardware access and C library
- Application layer, either ...
 - AT commands (standard on ESP-01)
 - IoT demo (standard on ESP-12)
 - NodeMCU Lua interpreter
 - Your own application written in C

ESP-xx modules

- Variety of form factors, ESP-01 through ESP-12 ...
 - Antenna: None, Chip, PCB or UFL connector
 - Which pins broken out and layout (2 mm pitch)
- Power: 3.3V typical, 3.0V min, 3.6V max
- Chip enable pin (CH_PD): Hold high
 - ESP-12 dev board does this for you
- GPIO0: Hold low on power-up to enter boot loader
 - Flash firmware
 - After power-up, can use GPIO0 as button input

ESP-01 set-up

- PCB antenna
- 8 pins including UART Rx/Tx, GPIO (2), Reset
- No power regulator, use only 3.0V to 3.6V
- Need a means of holding GPIO0 low for firmware flash
- Standard firmware: AT commands
- Cable or use JohnS ESPkit-01 ...
 - | ESP-01 | | USB serial adaptor |
|---------|---|---|
| 1 RXD | ← | TXD |
| 2 VCC | — | VCC 3.3V |
| 3 GPIO0 | — | Connect to ground during power-up to flash firmware |
| 4 RESET | — | VCC 3.3V |
| 5 GPIO2 | | |
| 6 CH_PD | — | VCC 3.3V |
| 7 GND | — | GND |
| 8 TXD | → | RXD |

ESP-12 dev board set-up

- PCB antenna
- 16 pins inc. UART Rx/Tx, GPIO (9), ADC, Reset
 - RGB LED GPIOs: Red = 8, Green = 6, Blue = 7
- Uses 3x AA batteries with on-board 3.3v regulator
- Provides GPIO0 header for firmware flash
- Standard firmware: IoT demo
- Cable: Note ESP-12 dev board labels are confusing !
 - | ESP-12 | | USB serial adaptor |
|--------|---|--------------------|
| RXD | ← | RXD |
| GND | — | GND |
| TXD | → | TXD |

esptool overview

- Cross-platform Python, requires pySerial
 - <https://github.com/themadinventor/esptool>
- Various functions ...
 - Flash firmware
 - Create bootable image from binary blobs
 - Read MAC address
 - Read chip identification
 - Read / write memory
- Hold GPIO0 low and power cycle ESP8266

esptool flash firmware

- Flash standard NodeMCU pre-built image ...
 - Download image ...
 - <https://github.com/nodemcu/nodemcu-firmware>
 - `esptool -p SERIAL_PORT write_flash 0x00000 nodemcu_20150212.bin`
- Flash NodeMCU image with WS2812B support
 - https://github.com/geekscap/esp8266_nodemcu_examples/firmware
 - `esptool -p SERIAL_PORT write_flash 0x00000
nodemcu_dev_0x00000.bin 0x10000 nodemcu_dev_0x10000.bin`

NodeMCU firmware

- eLua interpreter including ESP8266 SDK API
- NodeMCU API documentation ...
 - https://github.com/nodemcu/nodemcu-firmware/wiki/nodemcu_api_en
- Serial terminal connection at 9,600 baud
 - Command line prompt is “> “
 - Enter valid Lua statements
- Starts with around 23Kb heap available
 - Need to take care with your memory consumption
- Further reading: nodemcu.com/index_en.html

NodeMCU API

- `node.restart()`, `heap()`, `compile()`
- `file.format()`, `list()`, `remove()`, `open()`, `read()`, `write()`
- `wifi.sta`, `wifi.ap` sub-modules
- `net` module: TCP and UDP client and server
- `mqtt` module: Message Queue Telemetry Transport
- `timer` module, `tmr.alarm()`, `tmr.stop()`, `tmr.time()`
- `gpio.mode()`, `read()`, `write()`, `trig()`
- `pwm`, `adc`, `i2c`, `spi`, `one-wire` modules
- `bit` module: bit-wise logical operations

Lua introduction - I

- <http://www.lua.org/start.html>
- `print(1 + 2); print("hello"); print(node.heap())`
- Variables: boolean, numbers, strings, tables
 - Global by default, but can use “local” keyword
 - Variable type declarations are not required
 - `colour = {}; colour["red"] = 1; colour["blue"] = 2`
- Functions are first-class values
 - `function name(parameters)`
 `return value` - - Can return multiple values
 `end`

Lua introduction - 2

- Control-flow ...
 - if *condition* then
 print(true)
else
 print(false)
end
 - for *variable = first, last, delta* do
end
 - while *condition* do
end

Lua introduction - 3

- NodeMCU after boot will try to run “init.lua”
- Compile using `node.compile(“file.lua”)`
 - Byte-code written to “file.lc”
 - Save memory
- Modules ...
 - `moduleA = require(“module.lua”)`
 - ```
local module = {}
function module.name()
end
return module
```

# NodeMCU example

- You can't just type ... `print(file.list())` !
- You need to type ...
  - `for n,s in pairs(file.list()) do print(n.." size: "..s) end`
  - `file.list()` ... returns a table
  - `pairs()` ... returns an iterator
  - `for n,s in ...` loops through each iterator pair
    - `n` = file name, `s` = file size



# ESPlorer IDE

- Simplify process of managing files and running scripts on NodeMCU or MicroPython
- Also short-cuts for AT commands firmware
- <http://esp8266.ru/esplorer>
- Open source ...
  - <https://github.com/4refr0nt/ESPlorer>
- Start via command line ... `java -jar ESPlorer.jar`
  - Scans for available serial ports
  - Provides Graphical User Interface for development

# ESPlorer IDE

The screenshot displays the ESPlorer IDE interface, version 0.1 build 206 by 4refr0nt. The main window is divided into three panes:

- Left Pane (Code Editor):** Displays a Lua script named `setup.lua`. The script defines a `module` with functions `wifi_wait_ip()`, `wifi_start(aps)`, and `module.start()`. It includes comments and uses the `wifi` and `tmr` modules.
- Right Pane (Terminal):** Shows the output of the script execution. It includes the message `PORT OPEN 9600`, the command `node.restart()`, and the output `> L(00000190DL S0bRS0000D000`. Below this, it shows the NodeMCU version `0.9.5 build 20150214` and the Lua version `5.1.4`. The command `> lifx_button` is also visible.
- Bottom Pane (Terminal):** Shows the output of the script execution, including the command `node.restart()` and the output `> L(00000190DL S0bRS0000D000`.

The interface also features a sidebar on the right with a list of snippets (Snippet0 to Snippet15) and a bottom bar with buttons for `Save to ESP`, `Send to ESP`, `ESP Cat`, `Remove`, `File List`, `Reset ESP`, and `DoFile`.

# Button input

- Connect button between GPIO0 and Ground
- Example code ...
  - [https://github.com/geekscap/esp8266\\_nodemcu\\_examples/blob/master/examples/button.lua](https://github.com/geekscap/esp8266_nodemcu_examples/blob/master/examples/button.lua)
  - Load into ESPlorer IDE: File -> Open
  - Save to ESP8266: [Save to ESP]
  - Run script: [Do File]
- ESP-12 bonus: Try to use LDR and `adc.read()`

# Button input - FAIL

- Our first attempt is likely to look like this ...

```
PIN_BUTTON = 3 -- GPIO0
```

```
gpio.mode(PIN_BUTTON, gpio.INPUT, gpio.PULLUP)
```

```
while true do
```

```
 if gpio.read(PIN_BUTTON) == 0 then
```

```
 print("BUTTON PRESSED")
```

```
 tmr.delay(20000) - - microseconds
```

```
 end
```

```
end
```



# Button input

- ... but previous example, after a short while it fails :(
- More reliable to use timers, rather than delays
- Also, code is much more modular and re-usable
- Try ... `tmr.alarm(id, interval, repeat_flag, function)`
  - `id`: timer number 0 to 6
  - `interval`: alarm time in milliseconds
  - `repeat_flag`: 0 = once, 1 = repeat until `tmr.stop()`
  - `function`: Lua function to invoke
- The following code is more reliable ...

```
PIN_BUTTON = 3 -- GPIO0
TIME_ALARM = 25 -- 0.025 second, 40 Hz
gpio.mode(PIN_BUTTON, gpio.INPUT, gpio.PULLUP)
button_state = 1
button_time = 0
```

```
function buttonHandler()
 button_state_new = gpio.read(PIN_BUTTON)
 if button_state == 1 and button_state_new == 0 then
 button_time = tmr.time()
 print("BUTTON PRESSED")
 elseif button_state == 0 and button_state_new == 1 then
 button_time_new = tmr.time()
 if tmr.time() > (button_time + 2) then
 tmr.stop(1)
 print("BUTTON DISABLED")
 end
 end
 button_state = button_state_new
end
```

```
tmr.alarm(1, TIME_ALARM, 1, buttonHandler)
```

# Regular LED output

- Connect LED and current limiting resistor between GPIO2 and Ground
- Example code ...
  - [https://github.com/geekscap/esp8266\\_nodemcu\\_examples/blob/master/examples/led.lua](https://github.com/geekscap/esp8266_nodemcu_examples/blob/master/examples/led.lua)
  - Load into ESPlorer IDE: File -> Open
  - Save to ESP8266: [Save to ESP]
  - Run script: [Do File]
  - Try ... init.lua: dofile('led.lua')

# Regular LED output

```
LED_PIN = 4 -- GPIO2
TIME_ALARM = 500 -- 0.5 second
```

```
gpio.mode(LED_PIN, gpio.OUTPUT)
```

```
led_state = gpio.LOW
```

```
function ledHandler()
```

```
 if led_state == gpio.LOW then
```

```
 led_state = gpio.HIGH
```

```
 else
```

```
 led_state = gpio.LOW
```

```
 end
```

```
 gpio.write(LED_PIN, led_state)
```

```
end
```

```
tmr.alarm(1, TIME_ALARM, 1, ledHandler)
```



# WS2812B LED output

- Original development by Markus Gritsch
  - <http://www.esp8266.com/viewtopic.php?f=21&t=1143>
- Isn't yet part of the NodeMCU master branch
- `BRIGHT = 0.1; ON = BRIGHT * 255`  
`LED_PIN = 4 -- GPIO2`  
`PIXELS = 8`  
`RED = string.char( 0, ON, 0)`  
`GREEN = string.char(ON, 0, 0)`  
`BLUE = string.char( 0, 0, ON)`  
`ws2812.write(LED_PIN, RED:rep(PIXELS))`  
`ws2812.write(LED_PIN, GREEN:rep(PIXELS))`  
`ws2812.write(LED_PIN, BLUE:rep(PIXELS))`

# WS2812B LED example

- Connect WS2812B to GPIO2
- Example code ...
  - [https://github.com/geekscap/esp8266\\_nodemcu\\_examples/blob/master/examples/ws2812.lua](https://github.com/geekscap/esp8266_nodemcu_examples/blob/master/examples/ws2812.lua)
- Load into ESPlorer IDE: File -> Open
- Save to ESP8266: [Save to ESP]
- Run script: [Do File]
- Try ... init.lua: dofile('ws2812.lua')

# Setting up Wi-Fi client

- Scan to get available Wi-Fi Access Points ...
  - `wifi.sta.getap(function)`
  - Calls function when list of Access Points is ready
- Start Wi-Fi station (client) ...
  - `wifi.setmode(wifi.STATION);`
  - `wifi.sta.config("ssid", "passphrase")`
  - `wifi.sta.connect()`
- Returns your IP address when ready ...
  - `wifi.sta.getip()`

- `wifi.sta.getap(wifi_start)`
- `module.SSID = {}`  
`module.SSID["SSID1"] = "passphrase1"`  
`module.SSID["SSID2"] = "passphrase2"`
- `local function wifi_start(aps)`  
    `for key,value in pairs(aps) do`  
        `if config.SSID and config.SSID[key] then`  
            `wifi.setmode(wifi.STATION);`  
            `wifi.sta.config(key, config.SSID[key])`  
            `wifi.sta.connect()`  
            `tmr.alarm(1, 2500, 1, wifi_wait_ip)`  
        `end`  
    `end`  
`end`
- `local function wifi_wait_ip()`  
    `if wifi.sta.getip() then`  
        `tmr.stop(1)`  
    `end`  
`end`



# Wi-Fi client example - I

- Modular, flexible, timer-based application skeleton
- Example code ...
  - [https://github.com/geekscape/esp8266\\_nodemcu\\_examples/tree/master/skeleton](https://github.com/geekscape/esp8266_nodemcu_examples/tree/master/skeleton)
  - Load into ESPlorer IDE: File -> Open
  - Save to ESP8266: [Save to ESP]
  - Reset ESP8266
  - `print(wifi.sta.getip())`

# Wi-Fi client example - 2

- `init.lua`
  - Called on boot
  - Minimal, can't be compiled :(
- `config.lua`
  - Application configuration, e.g SSID and passphrases
- `setup.lua`
  - Sets up Wi-Fi depending upon your location
- `application.lua`
  - Your code, change filename as appropriate
- Use `node.compile()` on everything except `init.lua`

# UDP message transmit

- `socket = net.createConnection(net.UDP, 0)`  
`socket:connect(UDP_PORT, UDP_HOST_STRING)`  
`socket:send(MESSAGE)`  
`socket:close()`
- Example code ...
  - [https://github.com/geekscape/esp8266\\_nodemcu\\_examples/blob/master/applications/button\\_udp.lua](https://github.com/geekscape/esp8266_nodemcu_examples/blob/master/applications/button_udp.lua)
- Test on laptop with command line UDP server ...
  - `nc -l -u IP_ADDRESS 4000`

# UDP message receive

- `udp_server = net.createServer(net.UDP)`  
`udp_server:on("receive", function(srv, data)`  
`print("udp: " .. data)`  
`end)`  
`udp_server.listen(UDP_PORT)`
- `udp_server:close()`
- Example code ...
  - [https://github.com/geekscap/esp8266\\_nodemcu\\_examples/blob/master/applications/ws2812\\_udp.lua](https://github.com/geekscap/esp8266_nodemcu_examples/blob/master/applications/ws2812_udp.lua)
- Test on laptop with command line UDP client ...
  - `nc -u IP_ADDRESS 4000`



# MQTT client

- MQTT server address “192.168.0.32”
- ```
m:on("message", function(conn, topic, data)  
  print(topic .. ":" )  
  if data ~= nil then print(data) end  
end)
```

```
m:connect("192.168.0.32", 1883, 0, function(conn)  
  print("connected")  
end)
```

```
m:subscribe("/topic",0, function(conn)  
  print("subscribe success")  
end)
```

```
m:publish("/topic","hello",0,0, function(conn)  
  print("sent")  
end)
```

```
m:close();
```

ESP8266 / NodeMCU resources

- ESP8266 general information
 - <https://nurdspace.nl/ESP8266>
 - https://nurdspace.nl/images/e/e0/ESP8266_Specifications_English.pdf
- NodeMCU API documentation
 - https://github.com/nodemcu/nodemcu-firmware/wiki/nodemcu_api_en
- Lua programming language: <http://www.lua.org>
- ESPlorer IDE
 - <http://esp8266.ru/esplorer>
- esptool (cross-platform) for flashing firmware
 - <https://github.com/themadinventor/esptool>