ESP32 RMT Pulse Library for B4R (Pre-release)

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Introduction

This B4R Library enables using the ESP32 RMT module to produce pulse signals.
It uses the ESP32 IDF API `rmt_tx` driver for channel config, memory symbol setting, and pulse TX.
IDF version V5.2+ is required.

⚠ This library is **not** a full implementation of RMT functionality.
It simply exploits the RMT module to generate pulses on GPIO pins with minimum complexity.

- Resolution is set to **1 µs** (1 tick) This is the minimum pulse width.
- Number of tx channels: [SOC dependent]. ESP32 has **8**, ESP32s3 has **4**, ESP32c3 has **2**, …
- Number of memory symbols: [SOC dependent]. ESP32 has **64**, ESP32s3 has **48**, ESP32c3 has **48**, …

To understand the RMT module in more detail, refer to the "Remote Control Peripheral (RMT)" section of the ESP-IDF documentation & the Technical Reference Manual.
⚠ Ensure to select the correct document for your SOC variant (e.g., ESP32, ESP32-S3, …).
Another helpful reference is Circuit Labs - Chapter 141: RMT Module of ESP32

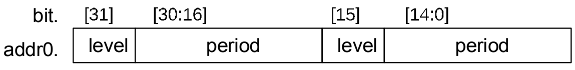
How the ESP32RMTpuls lib Works (Simplified)

From B4R:

1. Configure a RMT channel with: Channel num, GPIO pin, Output invert.
2. Send a pulse with: Channel num, Duration µs, Invert.
3. (optional) Apply PWM, GPIO routing, sync to the TX pulse.

Lib internal(C++):

- The RMT module has internal RAM (384x32 for ESP32s3), each 32bit word is a memory symbol that defines a pair of TX out logic states - duration0, level0 & duration1, level1. (duration = num of ticks)
  The symbols are sent sequentially to create a logic sequence waveform output.
- A memory symbol (`rmt_symbol_word_t`) is a 32-bit struct with:
  - `.duration0 (15 bits), .level0 (1 bit)`
  - `.duration1 (15 bits), .level1 (1 bit)`



RMT Symbol in RAM (32 bits)

Example:

```
symbol0: .duration0 = 10, .level0 = 1, .duration1 = 5, .level1 = 1
symbol1: .duration0 = 0, .level0 = 0  // <-- end-marker
```

Results in a **15 µs one-shot pulse**.
The following symbol with `.duration = 0` is used as a transmission **end-marker**.

- Pulse Modulation (PWM) uses 2 16bit values to apply a high or low level to the pulse.
  The sum of the 2 values is PWM period (frequency), the ratio of the 2 values is the PWM duty.
  The RMT driver has some issues, so carrier registers are set using ESP register macro's.
- In ESP-IDF, there's an encoder that translates bit patterns to memory symbols — **not used** in this library.

Example B4R Usage

Unzip the library **rESP32RMTpuls.zip** file to your ‘AdditionalLibraries’ B4R folder.
To run the test program: Copy the folder ESP32RMTpuls_test to your B4R data folder & open ESP32RMTpuls_test.b4r in B4R IDE.
For a new .br4, in the Libraries Manager of B4R IDE select the library from the list. (R-clik Refresh if needed).

```
Private RMT As ESP32RMTpuls                  ' <-- Put this line in Process_Globals
Private Const ch0 = 0, P2 = 2 As Byte        '     (can replace "RMT" with your preference)

RMT.channelConfig(ch0, P2, False)           ' Setup RMT channel (RMT ch, GPIO pin, Invert out)
RMT.TXpuls_us(ch0, 15, 0)                    ' 15µs pulse (RMT ch, PW  s, loop count)

                  ' --= Wait for a pulse to finish before starting a new pulse. =--
```

Pulse Duration Limits and default values

- Minimum pulse width = 1µs
- One RMT symbol half (.duration) = up to 32767 µs (65534 for 1 symbol)
- 47 symbols = **3080098 µs max or** 63 symbols = **4128642 µs max**
- With `Loop_cnt`, pulse duration can be multiplied up to 1023x:
  → 3080098000 µs (3080.0 seconds) **or** 4128642000 µs (4128.6 seconds) (1)

```
RMT.TXpuls_us(ch0, 1, 0)                    ' 1 µs pulse
RMT.TXpuls_us(ch0, 3145632, 1000)           ' ~52 min pulse
```

- RMT clk = APB_CLK (80mhz)
- RMT tick resolution = 1 µs
- Pulse Modulation(PWM): frequency Min.= 650hz - Max.=20mhz, Duty scale=1000.
  For freq. < 1221hz duty val will be clamped progressively < Duty max.

  Note 1.

  1x tick(res=1µs) may be added (if .duration**1**=0) to each loop for glitch free looping.

RMT Looping Explained

- **`Loop_cnt`** multiplies pulse duration:
  - **0** or **1** = x1
  - **2** = x2, 10 = x10
  - **-1** = **infinite loop** (pulse remains active like `digitalWrite` HIGH)
- Max supported loop: **1023** (RMT module limit - register bitfield [RMT_TX_LOOP_NUM_CHn])
- To cancel an indefinite loop call StopPuls(Tx_ch), to send a new pulse first call channelConfig(Tx_ch, GPIOn, Pin_Inv)

Library Function Calls

It is recommended to define constants for RMT channels and GPIO pins:

```
'Example:
Private Const ch0 = 0, ch1 = 1, ch2 = 2, ch3 = 3 As Byte
Private Const P2 = 2, P3 = 3, P4 = 4 As Byte
```

.channelConfig() - Configure RMT Channel

Setup channel ready for pulse data.

```
RMT.channelConfig(ch0, P2, False)
'   channelConfig(byte Tx_ch, byte GPIO_n, bool Inv_out)
```

.TXpuls_us() - Send Pulse (Microseconds)

Makes a pulse of microseconds duration. 1 to MAXµs [2]

```
RMT.TXpuls_us(ch0, 15000, 0)      ' 15 ms pulse
'   TXpuls_us(byte Tx_ch, ULong PW_us, int Loop_cnt)
```

.TXpuls_ms() - Send Pulse (Milliseconds)

Makes a pulse of milliseconds duration. 1 to MAXms [2]

```
RMT.TXpuls_ms(ch0, 15, 0)         ' 15ms pulse
'   TXpuls_ms(byte Tx_ch, ULong PW_ms, int Loop_cnt)
```

.TXpuls_s() - Send Pulse (Seconds)

Makes a pulse of seconds duration. (1 to MAXs) [2]

```
RMT.TXpuls_s(ch0, 10)         ' 10s pulse
'   TXpuls_s(byte Tx_ch, ULong PW_s)
```

.TXpulsTrain() - Send Pulse Train

Produces a pulse train of hi & lo states. Looping will multiply n pulses.
min. pulse=1µs, min. period=2µs, max. pulse=32766, max. period=32767, max. Puls_n = 47 or 63 [1]
Each pulse period occupies 1 RMT symbol.

```
RMT.TXpulsTrain(ch1, 10000, 20000, 40, 0) '40x pulse, 50hz 50% square wave.
'   TXpulsTrain(byte Tx_ch, ULong PW_us, ULong Prd_us, byte Puls_n, int Loop_cnt)
```

A Pulsetrain (with greater period) can also be created with other functions using loop x pulse, or applying PWM to a pulse (check pulse_µs / PWM period_µs to avoid last PWM period discrepancy)

Parameters

Tx_ch	**{byte}**	Channel number (eg., [0,1])
PW_us	**{ULong}**	Pulse Width µs
PRD_us	**{ULong}**	Period µs
Puls_n	**{ULong}**	Num of pulse [1]
Loop_cnt	**{ULong}**	Loop Count

Note 1. SOC dependent: 63 for ESP32, 47 for ESP32xx.

Note 2. Duration limits:
Max. duration is dependent on SOC.(ESP32, ESP32s3...) MAX_PULSE_US = (MAX_SYMBOLS - 1) x 65534. *See **Table 1.** SOC RMT difference*
eg. ESP32s3 MAX_SYMBOLS=48. 48-1 x 65534 = 3080098µs (3080.098ms, 3.080098s)
Multiplied by loop: 1023. (3154s or 52.5 minutes) for ESP32s3, (4227s or 70.45 minutes) for ESP32.

.TXpuls_prd() - Send Pulse with Period

Produces a pulse with period, (hi + lo state) when looped makes a square wave signal.
min. pulse=1 µs, min. period=0 µs, max. pulse=4,128,642 µs, period=4,128,642 µs [3]
With PRD_us <= PW_us, TX is a pulse only (period disabled).

```
RMT.TXpuls_prd(ch0, 70, 100, 20) '20x pulse, 10khz 70% duty square wave.
'   TXpuls_prd(byte Tx_ch, ULong PW_us, ULong PRD_us, int Loop_cnt)
```

Note 3. SOC dependent: eg. 63x65534 for ESP32, 47x65534 for ESP32xx.

.PWMmod() - Pulse Modulation (PWM)

Apply PWM modulation to the active TX pulse
Freq_hz min.= 650, max.= 20,000,000. Duty scale = 1000 (1 to 1000, 0= disable)

```
RMT.PWMmod(ch1, 30000, 500) ' 30khz modulation, 50% duty.
'   PWMmod(byte Tx_ch, ULong Freq_hz, UInt Duty_val);
```

Parameters

Tx_ch	**{byte}**	Channel number (eg., [0,1])
Freq_hz	**{ULong}**	Frequency hz
Duty_val	**{UInt}**	Duty value

Set the freq. & or Duty value = 0 to disable PWM.
Available Duty resolution is dependent on frequency. f > ~79khz will reduce to 1 @ 20Mhz.
Below ~79khz full scale resolution (1000) is available. At 20Mhz duty is fixed @50%.
For frequencies below ~1221 Hz, the duty value will be progressively clamped below the Duty scale maximum,
Example log: `Warning: Duty too high at 1000 Hz: Clamping Duty_val from 900 to 819 (max 81.9%)`
Using PWMmod(), effectively a pulse train(or burst) is produced at the PWM frequency.
Set pulse loop = -1 will produce an indefinite duration of PWM frequency.

.SYNC_ch() - Apply synchronization to selected channels

Configures and applies RMT channel sync group.

- Channels listed in `tx_channels` will be synchronized.
- Must call this *immediately before* triggering the first channel in the sync group.
- Do not transmit on unrelated channels between `SYNC_ch()` and the last group TX start, as they may be inadvertently included in the sync group (ESP-IDF behavior).
- Call SYNC_ch again before each new sync group TX to rearm the sync manager.
- There is typically a small delay between channels of 50ns ~ 1µs.(not guaranteed)

```
    Private RMTsync_ch() As Byte       ' Array to hold channel numbers.
    RMTsync_ch = Array As Byte(0, 1)   ' Channels  in sync.
    RMT.SYNC_ch(RMTsync_ch, 2, True)  '(chArray, numof_ch, True = apply, False = delete)
    '                          SYNC_ch(Byte() tx_channels, int numof_ch, bool SYNC_en)
```

Parameters

tx_channels	**{byte array()}**	of channel indices eg., (0,1)
numof_ch	**{byte}**	Number of channels in tx_channels()
SYNC_en	**{bool}**	True to enable, False to delete current sync manager

While the sync manager is suitable for aligning RMT waveforms within tight tolerances (~100 ns), applications requiring true simultaneous edge-triggered behaviour (such as motor commutation) may prefer peripherals like **MCPWM** with hardware-tied synchronization.

.SwitchGPIO() – Switch GPIO pin of RMT channel

Connect or disconnect a GPIO pin to/from an RMT TX channel at runtime.

- Ensure the GPIO pin is not already assigned to another peripheral output before connecting it to an RMT channel.
- To connect a pin only, set **`GPIO_dis = -1`**. (Allows multiple pins to output the same RMT signal.)
- To disconnect a pin only, set **`GPIO_con = -1`**.
- To maintain Invert out state(if set) set last parameter **`Inv_out`** to True

```
’ Example:
SwitchGPIO(0, 2, 3, False)    ’ Disconnect GPIO 2, connect GPIO 3 (no invert)
SwitchGPIO(0, -1, 3, False)   ’ Connect GPIO 3 only (keep existing outputs)
```

Parameters

- **`Tx_ch    {byte}`** RMT channel number
- **`GPIO_dis {int }`** GPIO to disconnect from the channel (-1 = no action)
- **`GPIO_con {int }`** GPIO to connect to the channel (-1 = no action)
- **`Inv_out  {bool}`** = True to invert the output signal

Application Example: Complementary PWM Output

```
Private Const ch0 = 0, P2 = 2, P3 = 3 As Byte
```

```
RMT.channelConfig(ch0, P2, False)    ’ Connect channel 0 to GPIO 2 (non-inverted)
RMT.PWMmod(ch0, 10000, 500)          ’ Setup 10kHz PWM at 50% duty
RMT.TXpuls_us(ch0, 30000, -1)        ’ Pulse duration 30000 µs x loop indefinitely
RMT.SwitchGPIO(ch0, -1, P3, True)    ’ Also output to GPIO 3, inverted
```

.InvOut() - Invert GPIO pin for RMT out

Invert GPIO pin. This will apply at the time when set(no synchronization).
This can also be applied to any other GPIO pin.
RMT idle level & PWM also follow inversion.

```
RMT.InvOut(P2, True) ’ invert GPIO
’   InvOut(byte GPIO_n, bool Pin_Inv)
```

.StopPuls() - Stop Pulse

Stops the RMT channel output and de-configures the channel. so re-config is required to start again.

```
RMT.StopPuls(ch0)
’   StopPuls(byte Tx_ch)
```

Notes: (Function calls)

- Setting **`invert = True`** during config applies to **all** pulses on the channel.
- Calling **`RMT.InvOut`** inverts the output **any time** - Pulse active or channel idle.
- Invert also sets **idle state**, so use pull-up/down resistors to ensure correct reset level.
- After calling StopPuls, channelConfig needs to be called before a new pulse is TX.
- The lib will select appropriate RMT channel max. & mem buffer size for selected SOC. This must be considered when allocating channels & setting maximum pulse duration.
- Functions of type int may be called with error return. eg. **`err = RMT.TXpuls_us(ch0, 15000, 0)`**
  ESP-IDF errors logged may not return an error code. (this is W.I.P)

SOC Variants

The following SOC variants have differing RMT specifications.
For other SOC's not listed data has not yet been tabulated:

Table 1. SOC RMT difference

SOC	TX Channels	Symbols	RAM	Max µs per ch
ESP32	8	64	512x32	4,128,642
ESP32-S3	4	48	384x32	3,080,098
ESP32-C3	2	48	192x32	3,080,098
ESP32-xx	—	—	—	3,080,098

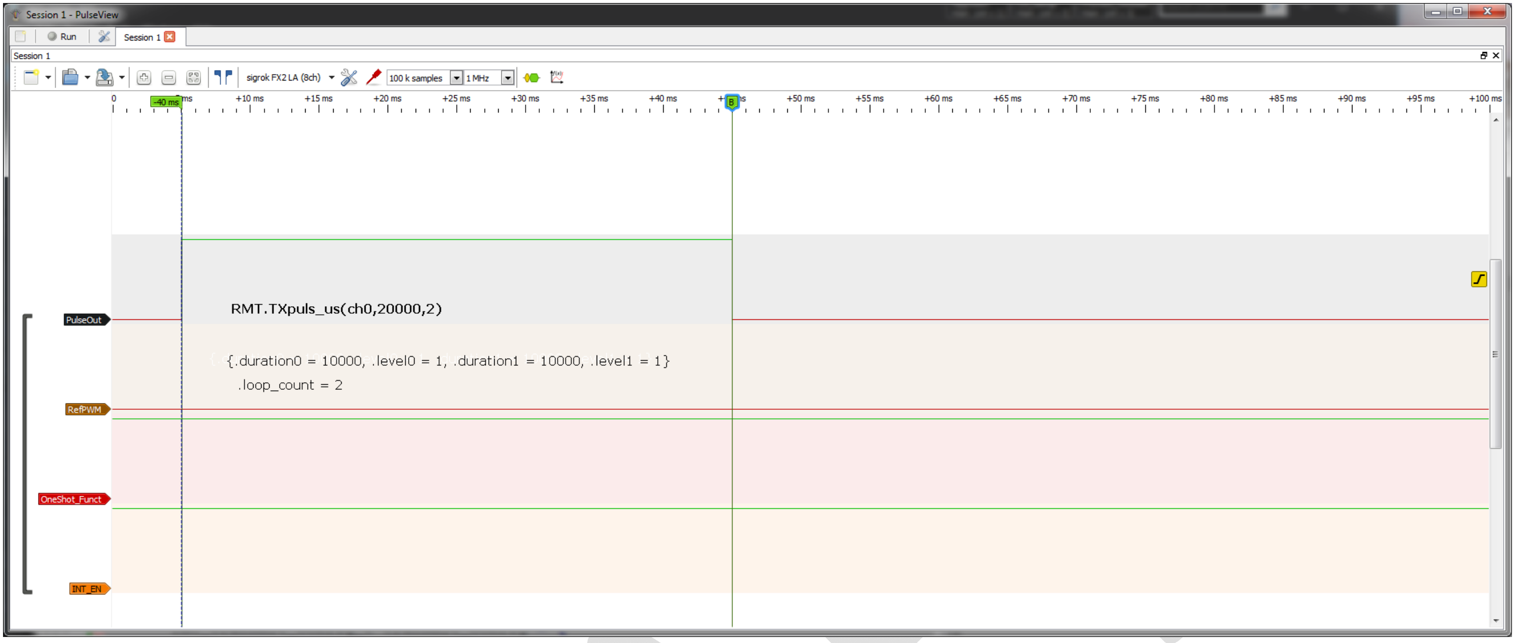
Notes:

- This lib requires Version >= **ESP-IDF v5.2**
- ESP-IDF will log errors it encounters. Check logs if you get unexpected results.
- Lib will log errors/warning for out of bound parameters(mostly).
- This lib is currently **Pre-release version**, expect possible issues.(& report please)
  If you want to enable verbose logging from lib code, enable Debug logs by un-commenting line **`//define DEBUG_LOG`**.
  There are also other debug code lines that can be un-commented, look for **`//::Serial.printf(...`**
  ! Serial.print will add a significant delay to each pulse, so don't forget to disable when done.
- For the same channel -when a pulse is active, a new pulse will be ignored.

Example output:

There is an example B4R test program ESP32RMTpuls.b4r, it contains various example tests for library functions.
Use comment un-comment to compile each test section.
Most examples would require a logicScope or oscilloScope to view output.

Pulse 40ms, RMT Symbol with Loop_cnt x Duration

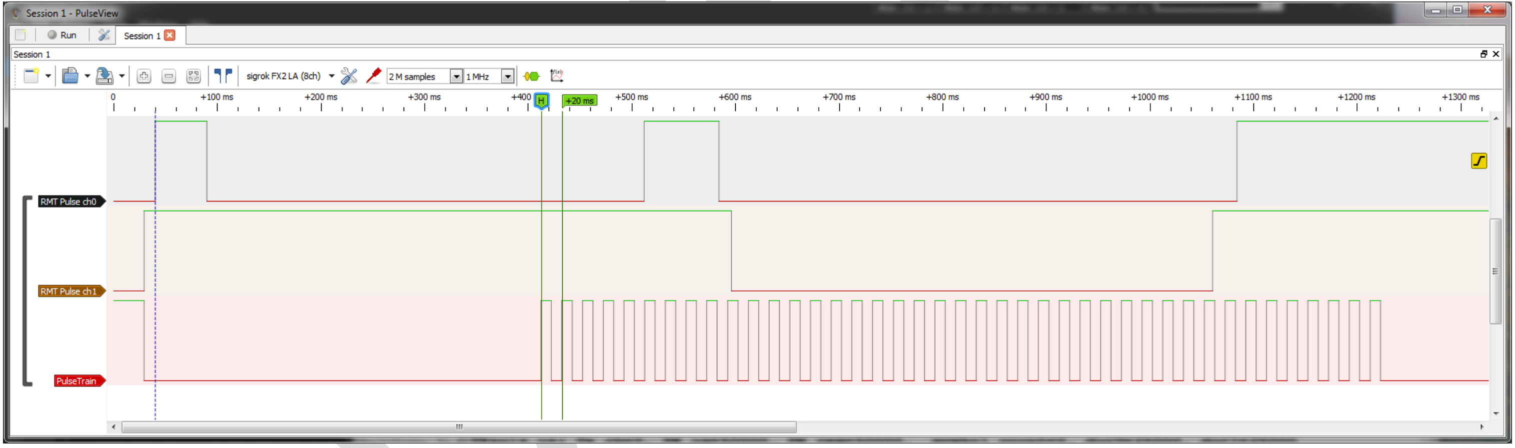


sigrok FX2 LA (8ch) 100 k samples 1 MHz

RMT.TXpuls_us(ch0,20000,2)

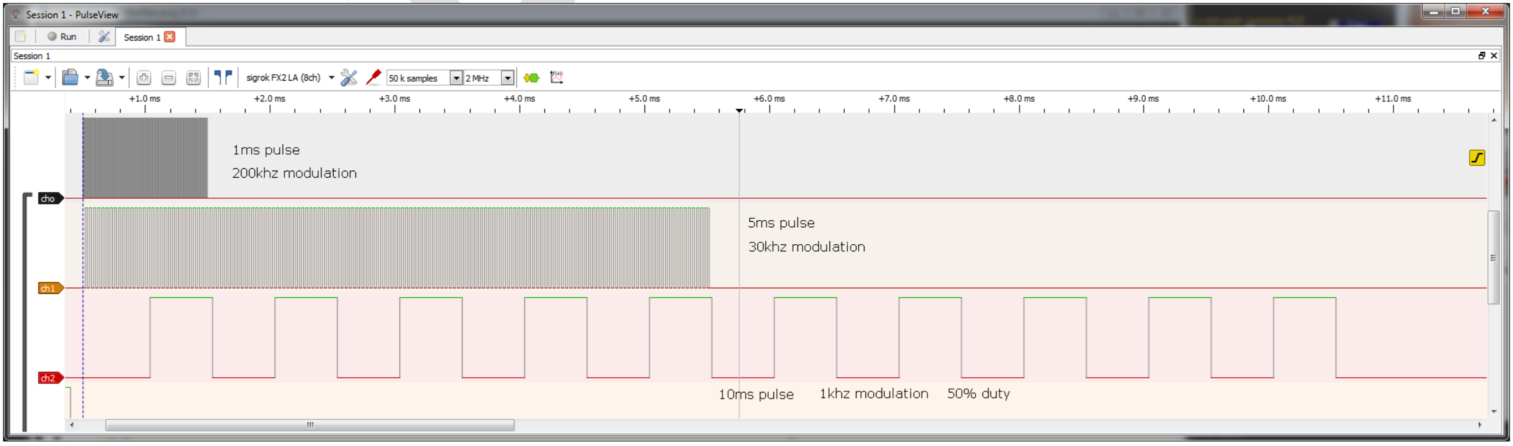
{.duration0 = 10000, .level0 = 1, .duration1 = 10000, .level1 = 1}
.loop_count = 2

Pulse on ch0, ch1, pulseTrain on ch2



sigrok FX2 LA (8ch) 2 M samples 1 MHz

Pulse Modulation 50% duty - 200khz, 10khz, 1khz



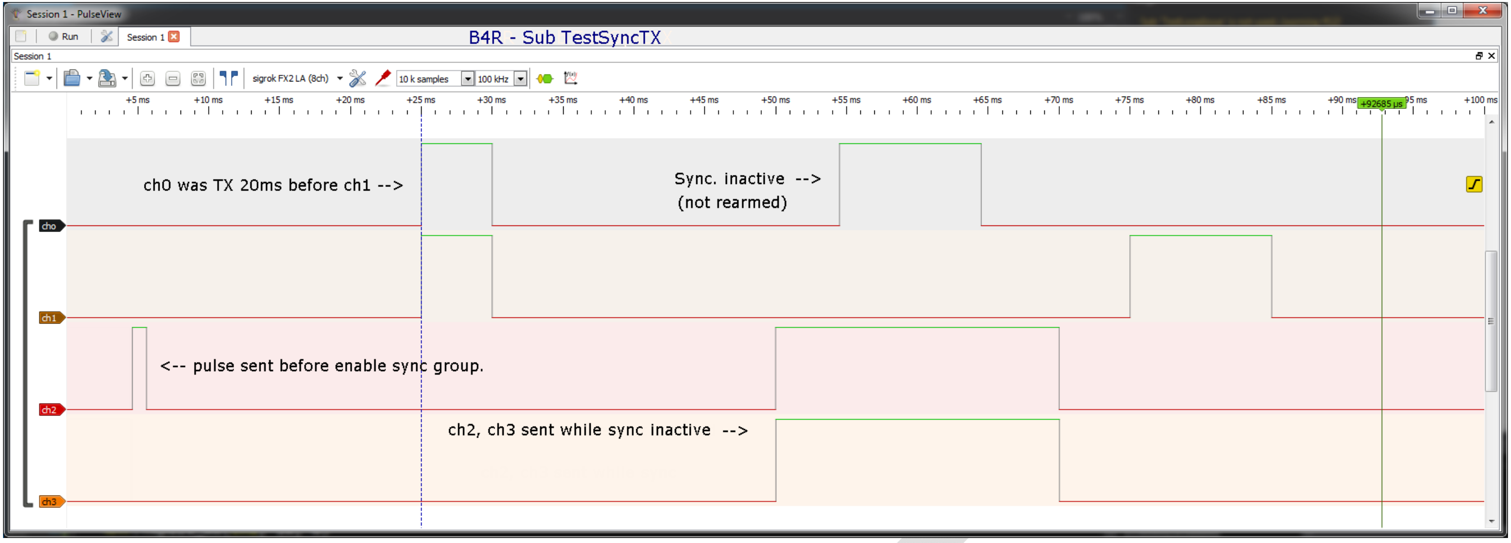
sigrok FX2 LA (8ch) 50 k samples 2 MHz

1ms pulse
200khz modulation

5ms pulse
30khz modulation

10ms pulse   1khz modulation   50% duty

Channel group sync. B4R - Sub TestSyncTX (ch0, ch1 are in sync group)



ch0 was TX 20ms before ch1 -->

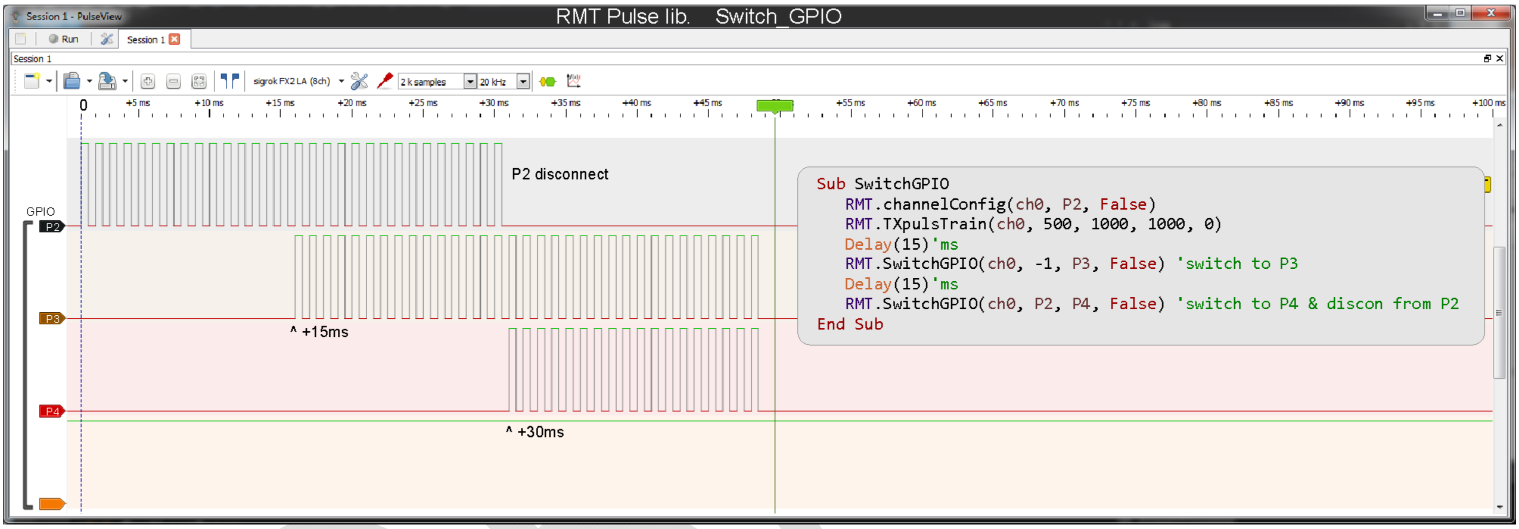
Sync. inactive -->
(not rearmed)

<-- pulse sent before enable sync group.

ch2, ch3 sent while sync inactive -->

GPIO routing - Connect or Disconnect GPIO to RMT channel

ToniG 2025.08.02



P2 disconnect

^ +15ms

^ +30ms

```
Sub SwitchGPIO
    RMT.channelConfig(ch0, P2, False)
    RMT.TXpulsTrain(ch0, 500, 1000, 1000, 0)
    Delay(15)'ms
    RMT.SwitchGPIO(ch0, -1, P3, False) 'switch to P3
    Delay(15)'ms
    RMT.SwitchGPIO(ch0, P2, P4, False) 'switch to P4 & discon from P2
End Sub
```

Library specific detail:

- This library is written in C++ for Arduino with ESP32, tested with Arduino-cli V1.2.0 & ESP-IDF v5.3.2
- The last symbol(MAX_SYMBOLS-1) in the buffer that is reserved for an end-marker at .duration0, is needed to enable glitch free looping.
- The lib uses default values for various settings to maintain "**K**eep**I**t**S**imple" in use.
  This is not a full featured RMT library, it is focused on "one shot" pulse generation.
- TXpuls_prd is the main pulse function, it is called from TXpuls_us, TXpuls_ms, TXpuls_s.
- ESP-IDF(5.3) crashes with out of range carrier values. This lib sets carrier registers direct.
- Carrier(PWM) is 2x 64bit register bitfields for hi & lo state, the sum of these is the PWM period.
- SwitchGPIO function modifies the GPIO matrix, this should be consistent across SOC variants & IDF versions.
- ESP-IDF has a function `rmt_tx_switch_gpio(channel, gpio_num, invert_out)`, it requires IDF Version > 5.4.2. It also is less versatile than SwitchGPIO(). It can be enabled by uncomment `//#define SW_GPIO_IDF` `in rESP32RMTpuls.cpp`

Disclaimer: Although care has been taken to capture specific technical detail, there may be errors in this document.