PWM overview

Contents

PWM overview

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This article gives information about the Linux®PWM framework.
It explains how to activate the PWM interface and, based on examples, how to use it.

Contents

1 Framework purpose

PWM (Pulse Width Modulation) framework offers a unified interface for the users to:

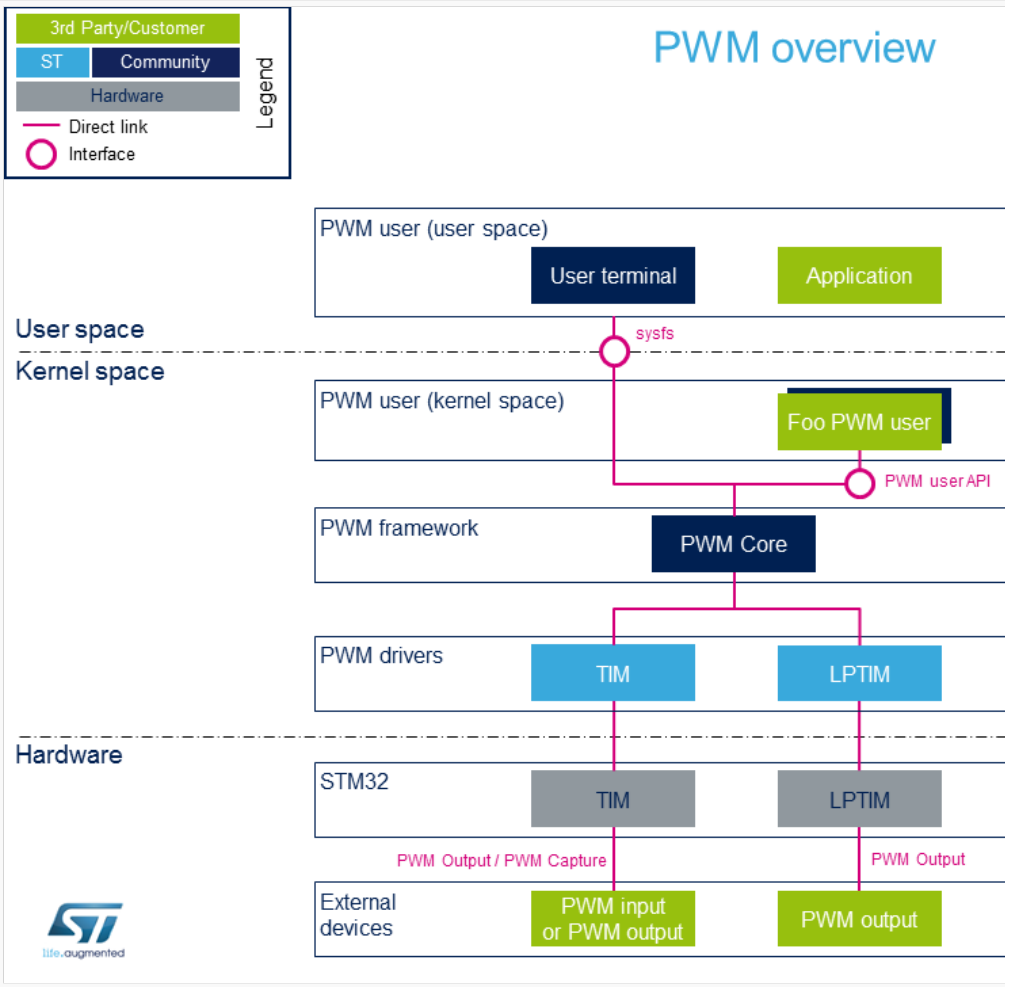
- control PWM output(s) such as period, duty cycle and polarity.
- capture a PWM signal and report its period and duty cycle (e.g. input).

The interface can be used from:

- user space (sysfs)
- kernel space (API)

PWMs can be used in various use cases, as mentioned in How to use the framework to control LEDs, beepers, vibrators or fans...

2 System overview



PWM Implementation architecture

2.1 Component description

- **PWM user** (User space)

The user can use PWM sysfs interface, from a user terminal or a custom application, to control PWM device(s) from user space.

- **PWM user** (Kernel space)

User drivers can use PWM API to control PWM external device(s) from kernel space (such as back-light, vibrator, LED or fan drivers).

- **PWM framework** (Kernel space)

The PWM core provides sysfs interface and PWM API. They can be used to implement PWM user and PWM controller drivers.

- **PWM drivers** (Kernel space)

Provider drivers such as STM32 TIM Linux driver and STM32 LPTIM Linux driver that expose PWM controller(s) to the core.

- **PWM hardware**

PWM controller(s) such as *TIM internal peripheral*[1] and *LPTIM internal peripheral*[2] used to drive external PWM controlled devices.

2.2 API description

Documentation on PWM interface can be found under kernel Documentation/pwm.txt

2.2.1 Kernel PWM API

The main useful user API are the following:

- **devm_pwm_get()** or pwm_get() / pwm_put(): this API is used to look up, request, then free a PWM device.
- **pwm_init_state()**, **pwm_get_state()**, **pwm_apply_state()**: this API is used to initialize, retrieve and apply the current PWM device state.
- **pwm_config()**: this API updates the PWM device configuration (period and duty cycle).
- ...

2.2.2 Sysfs interface

In addition to *Documentation/pwm.txt*[3] details on ABI are available in *Documentation/ABI/testing/sysfs-class-pwm*[4].

3 Configuration

3.1 Kernel configuration

Activate PWM framework in the kernel configuration through the Linux menuconfig tool, Menuconfig or how to configure kernel (CONFIG_PWM=y):

```
Device Drivers  --->
   [*] Pulse-Width Modulation (PWM) Support  --->
```

Activate PWM drivers for STM32 PWM drivers: STM32 TIM Linux driver and/or STM32 LPTIM Linux driver

3.2 Device tree configuration

- PWM generic DT bindings:

PWM DT bindings documentation[5] describes device tree properties related to standard **PWM user nodes** and **PWM controller nodes**.

- Detailed DT configuration for STM32 internal peripherals:

TIM device tree configuration and/or LPTIM device tree configuration

4 How to use the framework

PWM can be used either from the user or the kernel space.

4.1 How to use PWM with sysfs interface

The available PWM controllers are listed in sysfs:

```
Board $> ls /sys/class/pwm
pwmchip0
```

The number of channels per controller can be read in npwm (read-only)

```
Board $> cd /sys/class/pwm/pwmchip0
Board $> cat npwm
4
```

Each channel is exported (requested for sysfs activation) by writing the corresponding number in 'export'.

TIMx_CH1 is exported as **"pwm0"**, TIMx_CH2 as "pwm1", and so on:

- PWM channels are numbered from **0 to 'npwm' - 1**
- TIM[1] channels are numbered from **1 to 'npwm'**.

As an example, proceed as follows to export the first channel (TIMx_CH1, e.g. channel 0):

```
Board $> echo 0 > export
Board $> ls
device  export  npwm  power  pwm0  subsystem  uevent  unexport
```

The period and duty cycle must be configured before enabling any channel.

As an example, proceed as follows to set a period of 100 ms with a duty cycle of 60% on channel 0:

```
Board $> echo 100000000 > pwm0/period
Board $> echo 60000000 > pwm0/duty_cycle
Board $> echo 1 > pwm0/enable
```

The polarity can be inverted or set to normal by using the polarity entry:

```
Board $> echo "inversed" > pwm0/polarity
Board $> cat pwm0/polarity
inversed

Board $> echo "normal" > pwm0/polarity
Board $> cat pwm0/polarity
normal
```

4.2 How to use PWM capture with sysfs interface

PWM capture is available on some PWM controllers such as *TIM internal peripheral*[1] (see TIM configured in PWM input capture mode).

PWM output and capture mode are mutually exclusive on a TIM instance

```
# First export a channel (e.g. 0), then capture PWM input on it:
Board $> cd /sys/class/pwm/pwmchip0
Board $> echo 0 > export

Board $> cd pwm0
Board $> ls
capture  duty_cycle  enable  period  polarity  power  uevent

Board $> cat capture
10000 1002              # capture result is in nano-seconds, e.g.: 100KHz, 10% duty
cycle
```

4.3 Example of PWM usage with kernel PWM API

Several in-kernel drivers use kernel PWM API. Below a few examples:

- pwm-beeper: *drivers/input/misc/pwm-beeper.c*[6] driver, Documentation/devicetree/bindings/input/pwm-beeper.txt DT binding documentation.
- pwm-vibrator: *drivers/input/misc/pwm-vibra.c*[7] driver, Documentation/devicetree/bindings/input/pwm-vibrator.txt DT binding documentation.

5 How to trace and debug the framework

5.1 How to monitor with debugfs

PWM usage can be monitored from debugfs 'pwm' entry. For example:

```
Board $> cd /sys/kernel/debug/
Board $> cat pwm
platform/44000000.timer:pwm, 4 PWM
devices                                                    <-- One timer
instance exposes 4 PWM channels.
 pwm-0   (sysfs              ): requested enabled period: 1000000 ns duty: 500000 ns
polarity: normal   <-- Channel 0 has been exported, enabled and configured via sysfs
 pwm-1   ((null)             ): period: 0 ns duty: 0 ns polarity: normal
 pwm-2   ((null)             ): period: 0 ns duty: 0 ns polarity:
normal                              <-- Other channels aren't used currently
 pwm-3   ((null)             ): period: 0 ns duty: 0 ns polarity: normal
```

5.2 Troubleshooting PWM capture

Here are some clues on how to debug possible errors in PWM capture mode.
See How to use PWM capture with sysfs interface as a pre-requisite.

```
Board $> cat capture
cat: capture: Connection timed out
```

This may be due to:

- the input signal isn't recognized as a PWM input (or there's no input signal to capture).
- a wrong alternate function number is used for the input pin configuration in the device-tree.
  See "TIM configured in PWM input capture mode" for further details.

```
Board $> cat capture
cat: capture: Device or resource busy
```

This may be due to:

- a PWM channel on the same TIM instance is already running (in capture or output mode)

```
Board $> cat capture
cat: capture: No such device
```

This may be due to:

- the DMA isn't configured properly in the device-tree.
  See "TIM configured in PWM input capture mode" for further details.

```
Board $> cat capture
cat: capture: Function not implemented
```

This may be due to:

- a wrong TIM instance is being used (e.g. "/sys/class/pwm/pwmchip/pwmchipN"), and it doesn't support capture (like LPTIM)
- the DMA support isn't enabled (CONFIG_DMA_ENGINE)

6 References

- 1.01.11.2 TIM internal peripheral
- LPTIM internal peripheral
- Documentation/pwm.txt, Linux PWM interface overview
- Documentation/ABI/testing/sysfs-class-pwm, Linux PWM Application binary interface
- Documentation/devicetree/bindings/pwm/pwm.txt, PWM DT bindings documentation
- drivers/input/misc/pwm-beeper.c , Example to use kernel PWM API
- drivers/input/misc/pwm-vibra.c , Example to use kernel PWM API

Pulse Width Modulation

System File System (See https://en.wikipedia.org/wiki/Sysfs for more details)

Application programming interface

Light-emitting diode

low-power timer (STM32 specific)

Application binary interface. (In computer software, an application binary interface (ABI) describes the low-level interface between a computer program and the operating system or another program.)

Device Tree

Debug File System (See https://en.wikipedia.org/wiki/Debugfs for more details)

Direct Memory Access

TIM Linux driver

Stable: 16.01.2020 - 15:02 / Revision: 16.01.2020 - 14:58

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Return to TIM Linux driver.

LPTIM Linux driver

Stable: 16.01.2020 - 15:02 / Revision: 16.01.2020 - 14:58

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Return to LPTIM Linux driver.

Menuconfig or how to configure kernel

Stable: 22.04.2020 - 13:12 / Revision: 22.04.2020 - 13:10

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Return to Menuconfig or how to configure kernel.

TIM device tree configuration

Stable: 06.02.2020 - 15:04 / Revision: 06.02.2020 - 15:02

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Return to TIM device tree configuration.

LPTIM device tree configuration

Stable: 06.02.2020 - 14:42 / Revision: 06.02.2020 - 14:39

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Return to LPTIM device tree configuration.

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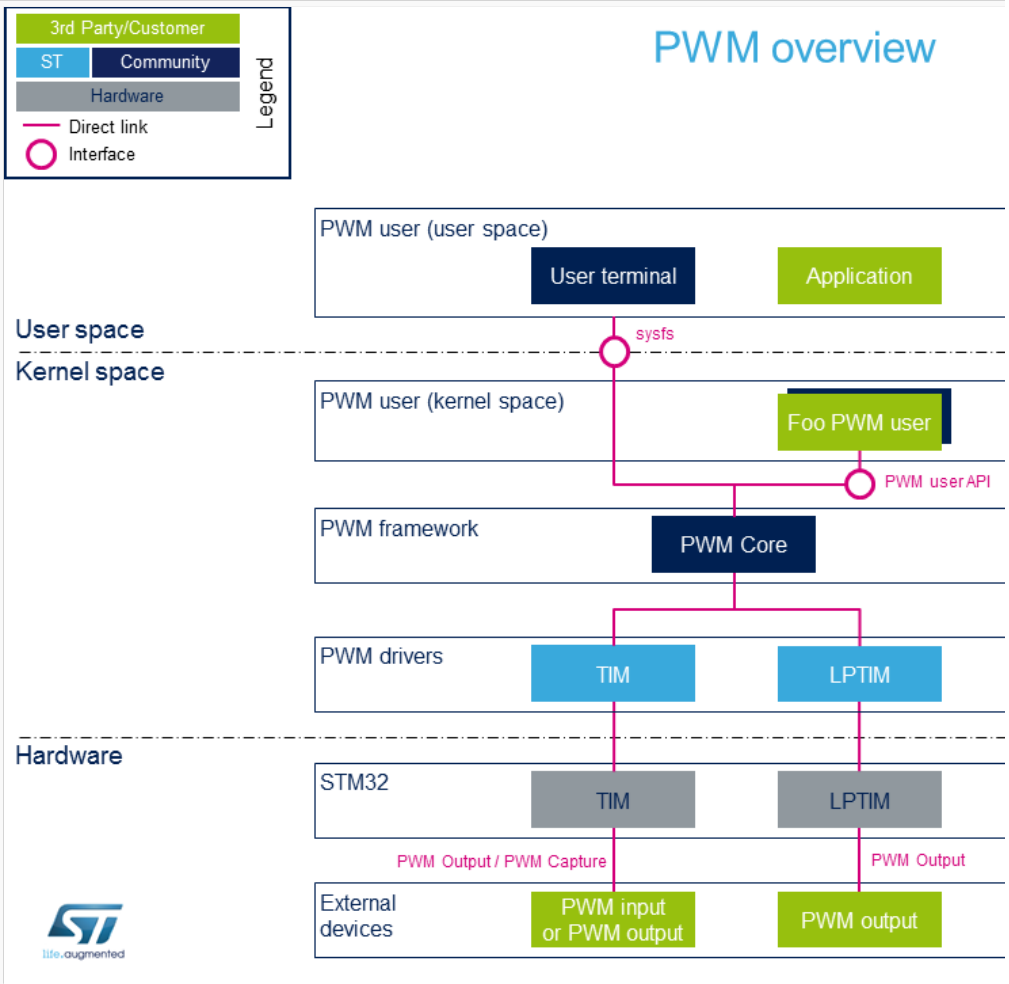

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Device Tree

Debug File System (See https://en.wikipedia.org/wiki/Debugfs for more details)

Direct Memory Access

Debugfs

Stable: 04.02.2020 - 07:47 / Revision: 04.02.2020 - 07:34

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Return to Debugfs.

TIM internal peripheral

Stable: 16.01.2020 - 14:30 / Revision: 16.01.2020 - 14:28

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Return to TIM internal peripheral.

LPTIM internal peripheral

Stable: 04.02.2020 - 15:59 / Revision: 04.02.2020 - 15:51

Invalid target: no reviewed revision corresponds to the given ID.

Return to LPTIM internal peripheral.