Building an SPI Device Driver

e-ale

Authors and license

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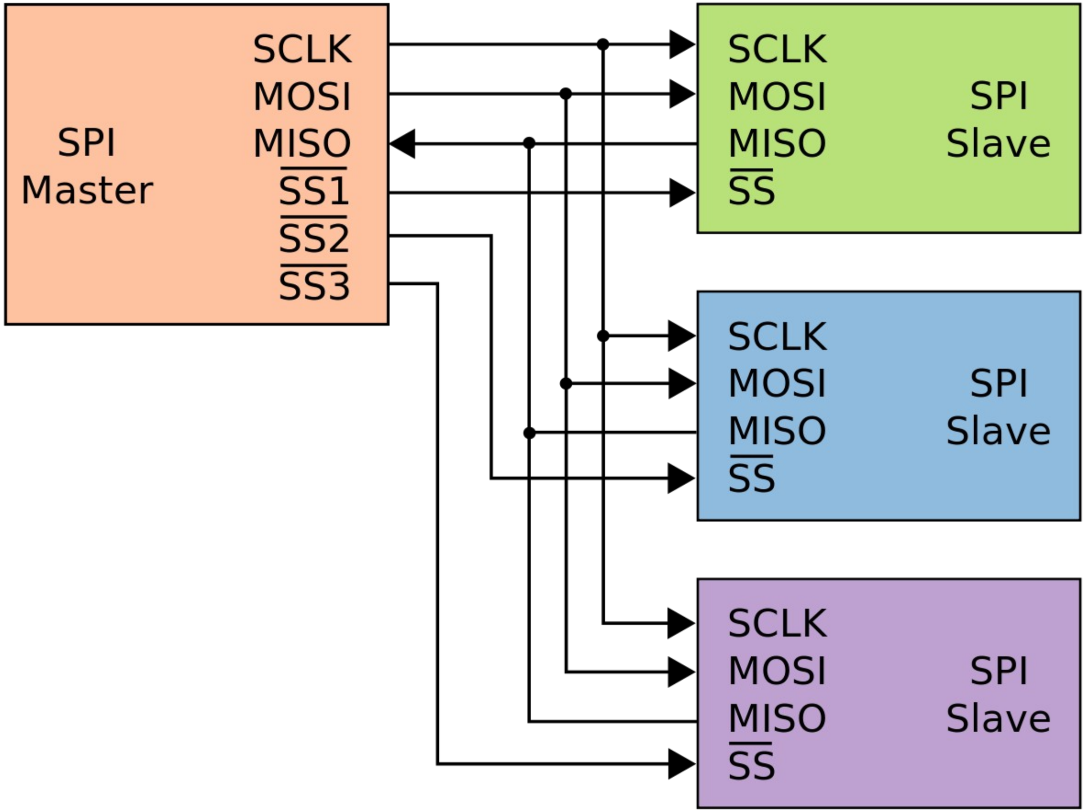
  -

What is SPI?

- SPI (Serial Peripheral Interface) is a full duplex synchronous serial master/slave bus interface.
- De facto standard, first developed at Motorola in the 1980s.
- A SPI bus consists of a single master device (**controller**) and possibly multiple slave devices (**devices**).
- Typical device interface
  - SCK – serial clock
  - MISO – master in slave out
  - MOSI – master out slave in
  - CSn / SSn – chip select / slave select
  - IRQ / IRQn – interrupt

Multiple-Device Network

- Single Master
- CLK/MOSI/MISO are shared
- Each device has a dedicated chip select



Graphic, Wikimedia Commons

Example SPI devices

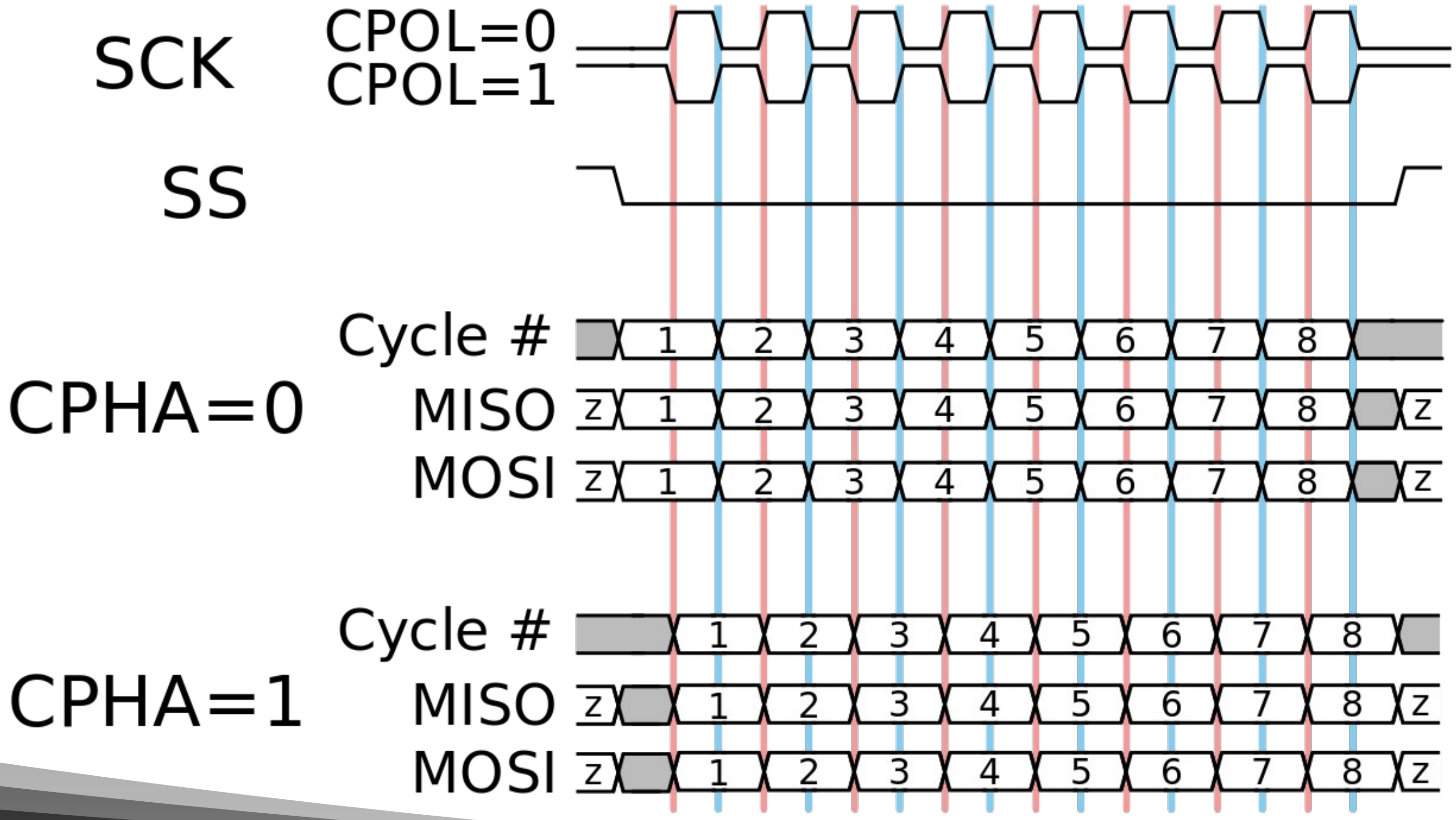
- Analog converters (ADC, DAC, CDC)
- Sensors (inertial, temperature, pressure)
- Serial LCD
- Serial Flash memory
- Touchscreen controllers
- FPGA programming interface

  – *There are many devices which use SPI, but SPI is most often used for devices where **higher speed** matters*

SPI Modes

- SPI **Mode** is typically represented by (CPOL, CPHA) tuple
  - **CPOL** – clock polarity
    - 0 = clock idles low
    - 1 = clock idles high
  - **CPHA** – clock phase
    - 0 = data latched on falling clock edge, output on rising
    - 1 = data latched on rising clock edge, output on falling
- Mode (0, 0) and (1, 1) are most commonly used.
- Sometimes listed in encoded form 0-3.

SPI Modes



Graphic, Wikimedia Commons

SPI Modes

- SPI **Mode** is often shown as a single number:
  - Mode 0: CPOL 0, CPHA, 0
  - Mode 1: CPOL 0, CPHA, 1
  - Mode 2: CPOL 1, CPHA, 0
  - Mode 3: CPOL 1, CPHA, 1

  - *Linux uses both terminologies*

Other Nuances

- While it’s technically possible to transfer any number of bits, most controllers will limit you to **multiples of 8-bits** (one byte).

- There is **only one clock**, which is used for **both input and output**.
  - When the clock moves, one bit of data is transferred **both** in and out of the device.
  - This may or may not be desirable.
  - Not all devices make use of this feature.
    - Some devices require the controller to send 0x0 (or other don’t-care value) while reading from the device.

Other Nuances

- The Chip Select is not only used to select which chip to communicate with:
  - You shouldn’t just tie it low for single-device networks

- The Chip Select is also used in many devices to **frame** a message.
  - This will delineate the beginning and end of a message.
  - This makes SPI, for most devices, a **message-oriented** protocol rather than simply a stream of data.
    - No special code or tokens are required to find the beginning or end of data in the stream.

Other Nuances

- In many chips, including SPI NOR Flash memory chips, it can be **difficult to detect errors** in the transmission, or even whether an SPI chip is **connected at all**.
  - Sending data to a non-existent chip will work fine on the controller side. It **doesn’t know** that nothing is connected.
  - An error will only be indicated when trying to **read**, when the read-back values are not as expected.
  - Be careful reading back, don’t just take 0xff data as valid, as maybe there is no device present!

User Space Tools

- In a typical embedded Linux environment, user space tools will be available to communicate with SPI devices.
- These tools typically use a kernel-space driver to do the work.

- An example is **mtd-tools**, which is used to read and write MTD devices.
  - MTD is linux-speak for Memory Technology Device, which is NOR or NAND flash memory.
  - flash_erase, flashcp (NOR)
  - nandwrite (NAND)
  - Others

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  - MTD is linux-speak for **Memory Technology Device**, which is NOR or NAND **flash memory**.
  - flash_erase, flashcp (NOR)
  - nandwrite (NAND)
  - http://www.linux-mtd.infradead.org/

Linux SPI Mailinglist

List: linux-spi;   (subscribe / unsubscribe)
Info:

This is the mailing list for the Linux SPI subsystem.

Archives:
    http://marc.info/?l=linux-spi
Footer:

To unsubscribe from this list: send the line "unsubscribe linux-spi" in the body of a message to majordomo@vger.kernel.org
More majordomo info at http://vger.kernel.org/majordomo-info.html

Controller Drivers

- Controller drivers are used to abstract and drive transactions on an SPI master.
- The host SPI peripheral registers are accessed by callbacks provided to the SPI core driver. (drivers/spi/spi.c)
- struct spi_controller

Controller Drivers

- Allocate a controller
  - **spi_alloc_master()**

- Set controller fields and methods
  - mode_bits - flags e.g. **SPI_CPOL, SPI_CPHA, SPI_NO_CS, SPI_CS_HIGH, SPI_RX_QUAD, SPI_LOOP**
  - **.setup()** - configure SPI parameters
  - **.cleanup()** - prepare for driver removal
  - **.transfer_one_message()/.transfer_one()** - dispatch one msg/transfer (mutually exclusive)

- Register a controller
  - **spi_register_master()**

Controller Devicetree Binding

The SPI controller node requires the following properties:
- compatible - Name of SPI bus controller following generic names recommended practice.

In master mode, the SPI controller node requires the following additional properties:
- #address-cells - number of cells required to define a chip select address on the SPI bus.
- #size-cells - should be zero.

Optional properties (master mode only):
- cs-gpios - gpios chip select.
- num-cs - total number of chipselects.

So if for example the controller has 2 CS lines, and the cs-gpios property looks like this:

```
cs-gpios = <&gpio1 0 0>, <0>, <&gpio1 1 0>, <&gpio1 2 0>;
```

Controller Devicetree Binding

Example:

```
spi1: spi@481a0000 {
	compatible = "ti,omap4-mcspi";
	#address-cells = <1>;
	#size-cells = <0>;
	reg = <0x481a0000 0x400>;
	interrupts = <125>;
	ti,spi-num-cs = <2>;
	ti,hwmods = "spi1";
	dmas = <&edma 42 0
		&edma 43 0
		&edma 44 0
		&edma 45 0>;
	dma-names = "tx0", "rx0", "tx1", "rx1";
	status = "disabled";
};
```

Protocol Drivers

- For each SPI device you intend on accessing, you have a protocol driver. SPI protocol drivers can be found in many Linux driver subsystems (iio, input, mtd).
- Messages and transfers are used to communicate to SPI devices via the SPI core and are directed to the respective controller driver transparently.
- A **struct spi_device** is passed to the probe and remove functions to pass information about the host.

Protocol Drivers

- Transfers
  - A single operation between controller and device
  - RX and TX buffers pointers are supplied
  - Option chip select behavior and delays

- Messages
  - Atomic sequence of transfers
  - Argument to SPI subsystem read/write APIs

struct spi_device

```
struct spi_device {
	struct device dev;
	struct spi_controller * controller;
	struct spi_controller * master;
	u32 max_speed_hz;
	u8 chip_select;
	u8 bits_per_word;
	u16 mode;
	int irq;
	void * controller_state;
	void * controller_data;
	char modalias;
	int cs_gpio;
	struct spi_statistics statistics;
};
```

Controller side proxy for an SPI device. Passed to the probe and remove functions with values based on the host configuration.

struct spi_device

```
#define SPI_CPHA      0x01                  /* clock phase */
#define SPI_CPOL      0x02                  /* clock polarity */
#define SPI_MODE_0    (0|0)                 /* (original MicroWire) */
#define SPI_MODE_1    (0|SPI_CPHA)
#define SPI_MODE_2    (SPI_CPOL|0)
#define SPI_MODE_3    (SPI_CPOL|SPI_CPHA)
#define SPI_CS_HIGH   0x04                  /* chipselect active high? */
#define SPI_LSB_FIRST 0x08                  /* per-word bits-on-wire */
#define SPI_3WIRE     0x10                  /* SI/SO signals shared */
#define SPI_LOOP      0x20                  /* loopback mode */
#define SPI_NO_CS     0x40                  /* 1 dev/bus, no chipselect */
#define SPI_READY     0x80                  /* slave pulls low to pause */
#define SPI_TX_DUAL   0x100                 /* transmit with 2 wires */
#define SPI_TX_QUAD   0x200                 /* transmit with 4 wires */
#define SPI_RX_DUAL   0x400                 /* receive with 2 wires */
#define SPI_RX_QUAD   0x800                 /* receive with 4 wires */
```

Probe Function

```
static int myspi_probe(struct spi_device *spi)
{
	struct myspi			*chip;
	struct myspi_platform_data	*pdata, local_pdata;

	...
}
```

Probe Function

```
static int myspi_probe(struct spi_device *spi)
{
	...
	match = of_match_device(of_match_ptr(myspi_of_match), &spi->dev);
	if (match) {
		/* parse device tree options */
		pdata = &local_pdata;
		...
	}
	else {
		/* use platform data */
		pdata = &spi->dev.platform_data;
		if (!pdata)
			return -ENODEV;
	}
	...
}
```

Probe Function

```
static int myspi_probe(struct spi_device *spi)
{
	...

	/* get memory for driver's per-chip state */
	chip = devm_kzalloc(&spi->dev, sizeof *chip, GFP_KERNEL);
	if (!chip)
		return -ENOMEM;

	spi_set_drvdata(spi, chip);


	...
	return 0;
}
```

OF Device Table

Example:

```
static const struct of_device_id myspi_of_match[] = {
	{
		.compatible = "mycompany,myspi",
		.data = (void *) MYSPI_DATA,
	},
	{ },
};
MODULE_DEVICE_TABLE(of, myspi_of_match);
```

SPI Device Table

Example:

```
static const struct spi_device_id myspi_id_table[] = {
        { "myspi", MYSPI_TYPE },
        { },
};
MODULE_DEVICE_TABLE(spi, myspi_id_table);
```

struct spi_driver

```
struct spi_driver {
	const struct spi_device_id * id_table;
	int (* probe) (struct spi_device *spi);
	int (* remove) (struct spi_device *spi);
	void (* shutdown) (struct spi_device *spi);
	struct device_driver driver;
};
```

struct spi_driver

Example:

```
static struct spi_driver myspi_driver = {
	.driver = {
		.name = "myspi_spi",
		.pm = &myspi_pm_ops,
		.of_match_table = of_match_ptr(myspi_of_match),
	},
	.probe = myspi_probe,
	.id_table = myspi_id_table,
};
module_spi_driver(myspi_driver);
```

Kernel APIs

- **spi_async()**
  - asynchronous message request
  - callback executed upon message complete
  - can be issued in any context

- **spi_sync()**
  - synchronous message request
  - may only be issued in a context that can sleep (i.e. not in IRQ context)
  - wrapper around spi_async()

- **spi_write()/spi_read()**
  - helper functions wrapping spi_sync()

Kernel APIs

- **spi_read_flash()**
  - Optimized call for SPI flash commands
  - Supports controllers that translate MMIO accesses into standard SPI flash commands

- **spi_message_init()**
  - Initialize empty message

- **spi_message_add_tail()**
  - Add transfers to the message’s transfer list

Device Node Devicetree Binding

SPI device nodes must be children of the SPI controller node.

One or more device nodes (up to the number of chip selects) can be present.

Required properties are:
- compatible - Name of SPI device following generic names recommended practice.
- reg - Chip select address of device.
- spi-max-frequency - Maximum SPI clocking speed of device in Hz.

Device Node Devicetree Binding

All device nodes can contain the following optional properties:
- spi-cpol - Empty property indicating device requires inverse clock polarity (CPOL) mode.
- spi-cpha - Empty property indicating device requires shifted clock phase (CPHA) mode.
- spi-cs-high - Empty property indicating device requires chip select active high.
- spi-3wire - Empty property indicating device requires 3-wire mode.
- spi-lsb-first - Empty property indicating device requires LSB first mode.

- spi-tx-bus-width - The bus width that is used for MOSI. Defaults to 1 if not present.
- spi-rx-bus-width - The bus width that is used for MISO. Defaults to 1 if not present.

- spi-rx-delay-us - Microsecond delay after a read transfer.
- spi-tx-delay-us - Microsecond delay after a write transfer.

Device Node Devicetree Binding

Example:

```
&spi1 {
	#address-cells = <1>;
	#size-cells = <0>;
	status = "okay";

	pinctrl-names = "default";
	pinctrl-0 = <&spi1_pins>;
	myspi@0 {
		compatible = "mycompany,myspi";
		spi-max-frequency = <2000000>;
		spi-cpha;
		...
		reg = <0>;
	};
	...
};
```

Device Tree Binding

- Walk-though of:
  - /opt/source/bb.org-overlays/src/arm/PB-SPI1-ETH-CLICK.dts
    - Ethernet controller
  - /opt/source/bb.org-overlays/src/arm/RoboticsCape-00A0.dts
    - spidev

User Space Direct access

- Linux also contains a driver allowing direct user space control of an SPI device.
  - spidev
  - Unlike with i2c, spidev requires explicit activation in the device tree in order to be bound to a device.
  - You can use compatible string “spidev” in your DT to bind the spidev driver to a device
    - *Discuss* :-D

  - *Sadly there is no automatic way to get spidev for devices which do not have drivers bound. This differs from i2c :(*

User Space Direct access

- Spidev is extremely useful for **prototyping**, or just getting the first comms with a new device.
  - Get the SPI mode right
    - You will get this wrong sometimes
      - Manufacturer datasheets are horribly inconsistent and confusing in this respect
  - Get some registers read. Figure out offsets
  - Make sure wiring is correct, configuration, speed, chip selects, etc.
  - Easy to recompile/iterate in userspace.
  - Probably won’t crash the kernel, most likely.

User Space Direct access

- Spidev can also be useful in production
  - Some SPI devices are simple, and more easily driven from user space
    - Some devices don’t use or require interrupts
    - Some use cases don’t require interrupts
      - Some use cases do not require any kind of special responsiveness
  - Embedded systems exist to solve your specific computing problem.
    - General case “wisdom” can be a disease
    - If it works for you, do it!

User Space Direct access

- Walk-though of:
  - include/linux/spi/spidev.h
  - tools/spi/spidev_test.c (kernel source)

Questions?

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