

Linux Power!

(from a perspective of a PMIC vendor)

Topics

- What and Why is a PMIC?
- Regulator provider/consumer
- Monitoring for abnormal conditions
- Setting safety limits
- A helper for sending notifications for “anomalies”

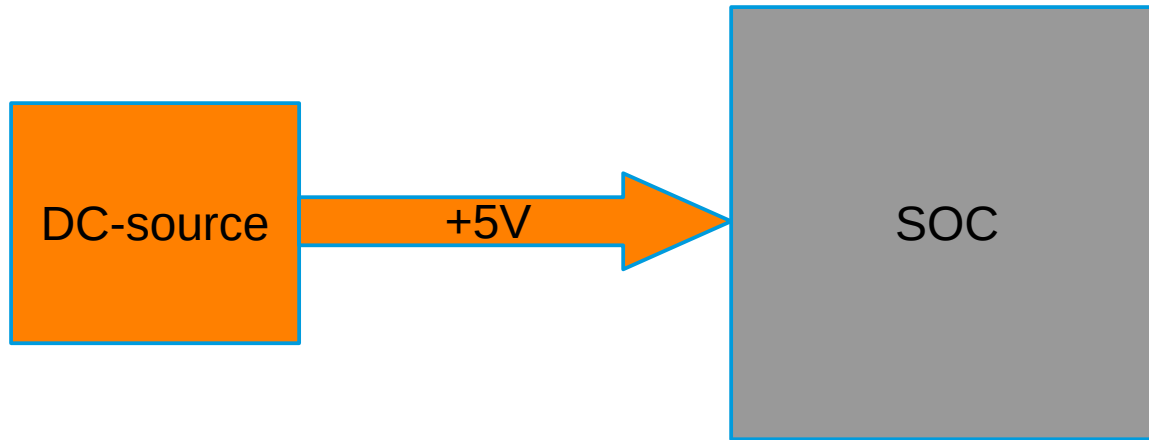
About me

- Matti Vaittinen
- Kernel/Driver developer at ROHM Semiconductor
- Worked at Nokia BTS projects (networking, clock & sync) 2005 – 2017
- Currently mainly developing/maintaining upstream Linux device drivers for ROHM ICs



Powering a processor

- Processor and peripherals need power
- Can be as simple as a dummy DC power source with correct voltage



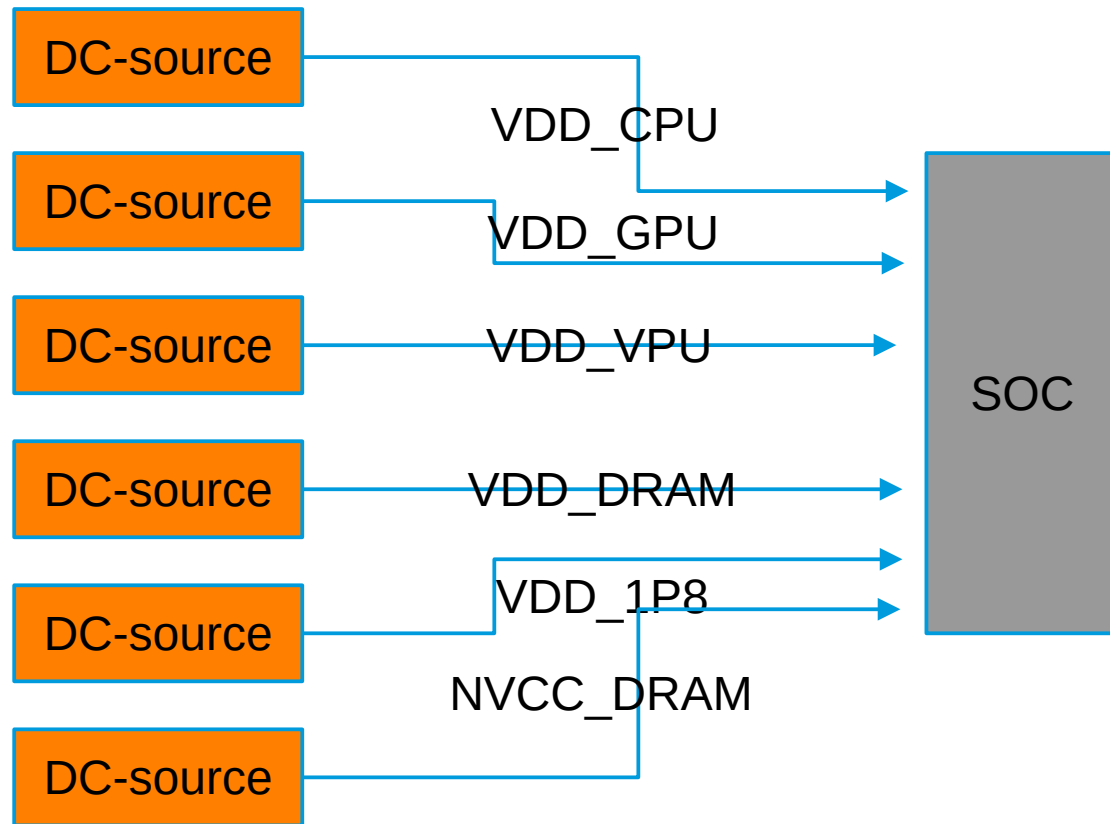
Powering a SOC these days

- Modern SOC's can have specific requirements

- Voltages

- Timings

=> Start-up/shut-down
sequence for power
sources



More control...

- Power savings by:
 - Shutting down not needed devices
 - Stand-by state(s)
 - DVS (Dynamic Voltage Scaling)

Automated power on

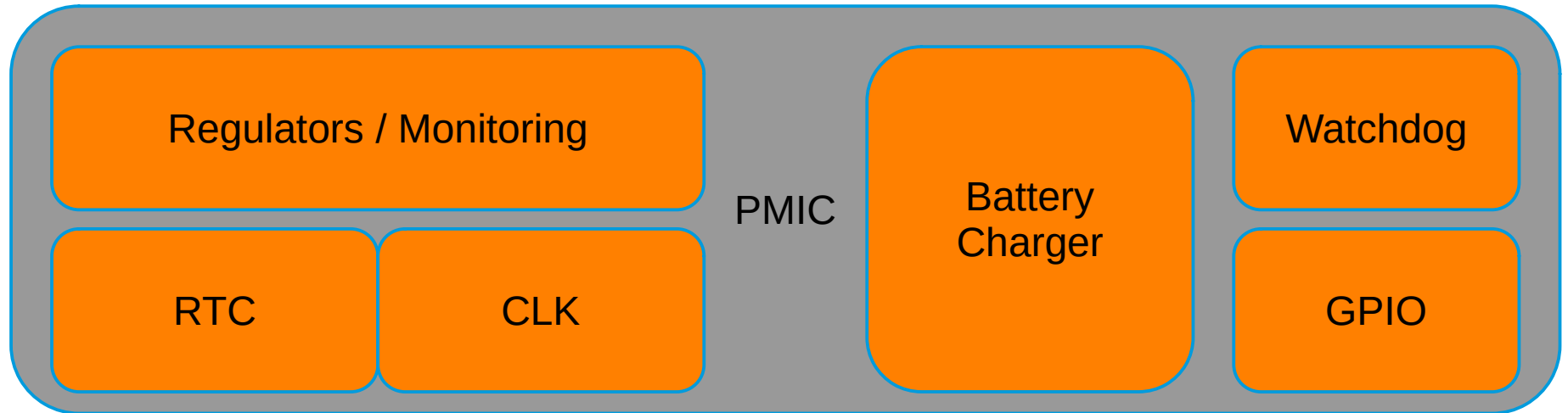
- Powering on a system at a given time...
 - RTC
- ...Or by event
 - HALL sensor, ...

More requirements...

- Battery / charger
- Watchdog
- Functional safety
 - Voltage monitoring
 - Current monitoring
 - Temperature monitoring

PMICs

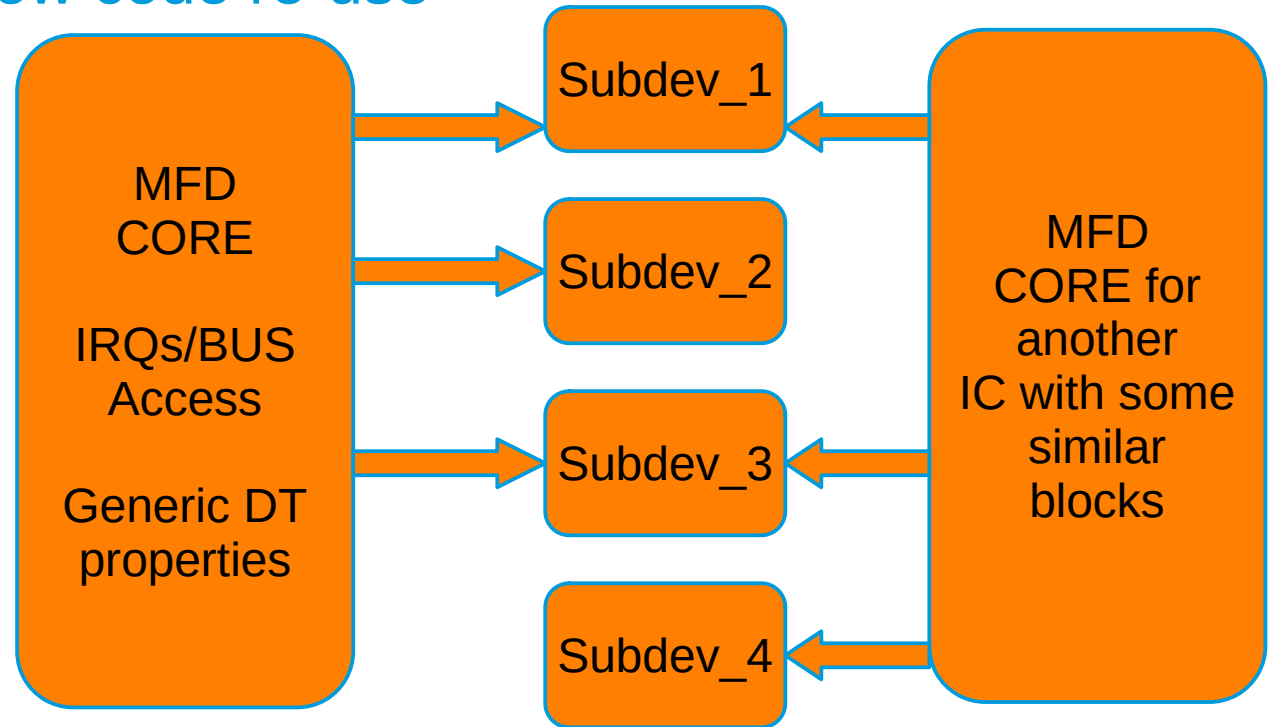
- PMIC – Power Management Integrated Circuit
 - Multiple DC sources with specific start-up/shut-down sequence + DVS
 - Auxiliary blocks to support various needs



Multi Function Devices

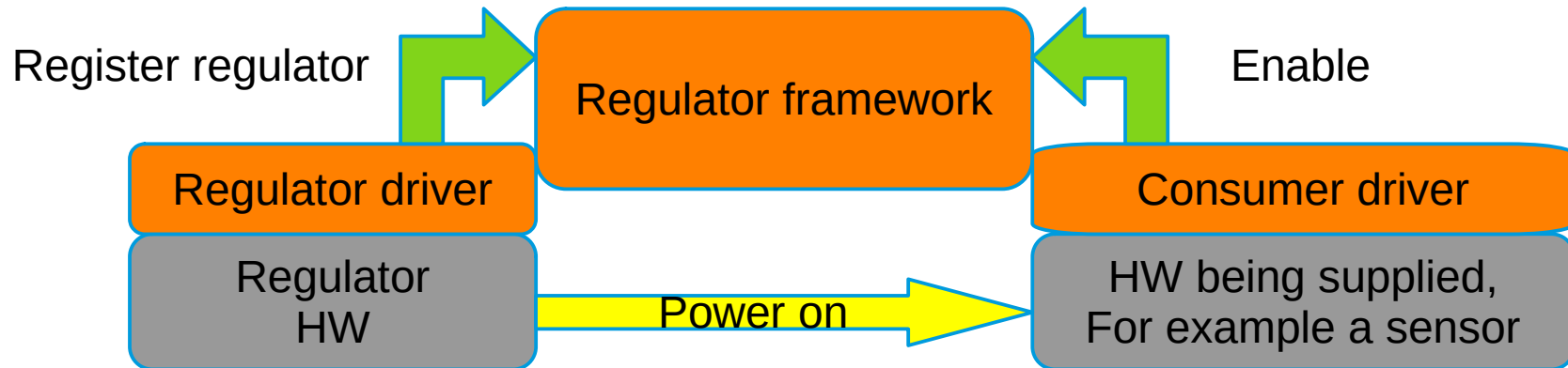
- Often MFD drivers. Allow code re-use

- **Regulator**
- RTC
- Power supply
- Watchdog
- GPIO
- CLK ...



Regulator provider / consumer

- Provider is driver interfacing the hardware. Eg, sits “below” the regulator framework. Between regulator framework and HW.
- Consumer is driver who wishes to control the regulator using the regulator framework. Eg, sits “on top of” the regulator framework.
- PMIC driver is the provider driver.



Detecting unexpected

- PMIC allows configuring safety-limits
 - Severity PROTECTION => Unconditional shutdown by HW.
 - Severity **ERROR** => **Irrecoverable error**, system not expected to be usable. Error handling by software.
 - Severity **Warning** => **Something is off-limit**, system still usable but a recovery action should be taken to prevent escalation to errors.



New(ish)
v5.14

Safety limits, devicetree

- Property format `regulator-<event>-<severity>-<unit>`

Examples:

`regulator-oc-protection-microamp`, `regulator-oc-error-microamp`, `regulator-oc-warn-microamp`

`regulator-ov-protection-microvolt`, `regulator-ov-error-microvolt`, ...

- Value 0 => disable, 1 => enable (with existing limit)
- others new limit

What if hardware does not support given limit?

Callbacks for configuring limits

```
struct regulator_ops {  
    // snip  
    int (*set_over_current_protection)(struct regulator_dev *, int lim_uA,  
                                       int severity, bool enable);  
    int (*set_over_voltage_protection)(struct regulator_dev *, int lim_uV,  
                                       int severity, bool enable);  
    int (*set_under_voltage_protection)(struct regulator_dev *, int lim_uV,  
                                       int severity, bool enable);  
    int (*set_thermal_protection)(struct regulator_dev *, int lim,  
                                  int severity, bool enable);  
  
};  
  
struct regulator_desc {  
    // snip  
    const struct regulator_ops *ops;  
};  
  
struct regulator_dev *devm_regulator_register(struct device *dev,  
                                              const struct regulator_desc *regulator_desc,  
                                              const struct regulator_config *config)
```

Example

```
static int bd9576_set_ocp(struct regulator_dev *rdev, int lim_uA, int severity,
                          bool enable)
{
    // snip

    /* Return -EINVAL for unsupported configurations */
    if ((lim_uA && !enable) || (!lim_uA && enable))
        return -EINVAL;

    /*
     * Select the correct register and appropriate register-value
     * conversion for given severity and limit..
     */
    if (severity == REGULATOR_SEVERITY_PROT) {
        // snip
    } else {
        // snip
    }

    /* Write configuration to registers */
    return bd9576_set_limit(range, num_ranges, d->regmap,
                           reg, mask, Vfet);
}
```

Informing the unexpected

- Regulator framework supports error (status) and notifications (events)
- Not all notifications are errors/warnings.
- Errors can be set by providers, queried by consumers
 - Polling
- Events can be sent by providers, subscribed by consumers
 - Notifying

Errors

[include/linux/regulator/consumer.h](#)

```
#define REGULATOR_ERROR_UNDER_VOLTAGE
#define REGULATOR_ERROR_OVER_CURRENT
#define REGULATOR_ERROR_REGULATION_OUT
#define REGULATOR_ERROR_FAIL
#define REGULATOR_ERROR_OVER_TEMP
#define REGULATOR_ERROR_UNDER_VOLTAGE_WARN
#define REGULATOR_ERROR_OVER_CURRENT_WARN
#define REGULATOR_ERROR_OVER_VOLTAGE_WARN
#define REGULATOR_ERROR_OVER_TEMP_WARN
```

Notifications

```
#define REGULATOR_EVENT_UNDER_VOLTAGE
#define REGULATOR_EVENT_OVER_CURRENT
#define REGULATOR_EVENT_REGULATION_OUT
#define REGULATOR_EVENT_FAIL
#define REGULATOR_EVENT_OVER_TEMP
...
#define REGULATOR_EVENT_UNDER_VOLTAGE_WARN
#define REGULATOR_EVENT_OVER_CURRENT_WARN
#define REGULATOR_EVENT_OVER_VOLTAGE_WARN
#define REGULATOR_EVENT_OVER_TEMP_WARN
#define REGULATOR_EVENT_WARN_MASK
```

Notifications

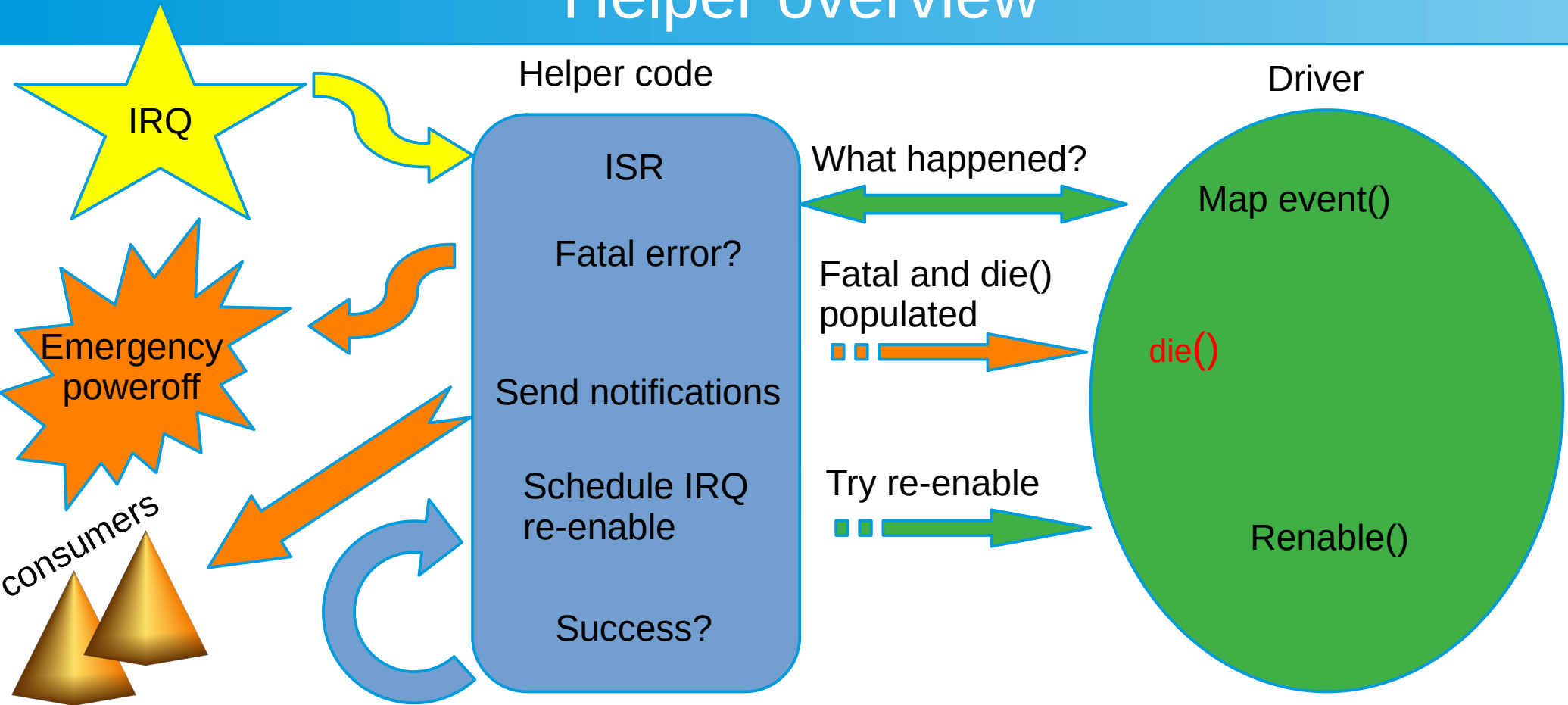
- Usually IRQ backed
 - PMIC detect error => IRQ => notification => consumer action(?)
- In many cases IRQ is held active for whole duration of error
 - Maybe because IRQs are considered as last thing to do(?)
 - Maybe because there is a need to ensure these IRQs are not missed(?)
 - Does not play well with all systems

Event IRQ helper

- Helper provided for IRQ handling and sending the notification.
 - Supports keeping IRQ disabled for period of time
 - Supports forcibly shutting down the system if accessing PMIC fails during error handling

```
void *regulator_irq_helper(struct device *dev,  
                           const struct regulator_irq_desc *d, int irq,  
                           int irq_flags, int common_errs, int *per_rdev_errs,  
                           struct regulator_dev **rdev, int rdev_amount);
```

Helper overview



Helper configuration

```
struct regulator_irq_desc {
    const char *name;
    int fatal_cnt;
    int reread_ms;
    int irq_off_ms;
    bool skip_off;
    bool high_prio;
    void *data;
    int (*die)(struct regulator_irq_data *rid);
    int (*map_event)(int irq, struct regulator_irq_data *rid,
                    unsigned long *dev_mask);
    int (*reable)(struct regulator_irq_data *rid);
};

void *regulator_irq_helper(struct device *dev,
                          const struct regulator_irq_desc *d, int irq,
                          int irq_flags, int common_errs, int *per_rdev_errs,
                          struct regulator_dev **rdev, int rdev_amount)

(or devm_-variant)
```

Event mapping data

```
struct regulator_err_state {  
    struct regulator_dev *rdev;  
    unsigned long notifs;  
    unsigned long errors;  
    int possible_errs;  
};
```

```
struct regulator_irq_data {  
    struct regulator_err_state *states;  
    int num_states;  
    void *data;  
    long opaque;  
};
```

```
int (*map_event)(int irq, struct regulator_irq_data *rid, unsigned long *dev_mask);  
int (*renewable)(struct regulator_irq_data *rid);
```

```
int regulator_irq_map_event_simple(int irq, struct regulator_irq_data *rid,  
                                   unsigned long *dev_mask)
```

Event mapping example

```
static int bd9576_ovd_handler(int irq, struct regulator_irq_data *rid,
                               unsigned long *dev_mask)
{
    ret = regmap_read(d->regmap, BD957X_REG_INT_OVD_STAT, &val);
    if (ret)
        return REGULATOR_FAILED_RETRY;

    rid->opaque = val & OVD_IRQ_VALID_MASK;
    *dev_mask = 0;

    if (!(val & OVD_IRQ_VALID_MASK))
        return 0;

    *dev_mask = val & BD9576_xVD_IRQ_MASK_VOUT1T04;

    for_each_set_bit(i, dev_mask, 4) {
        stat = &rid->states[i];

        stat->notifs      = rdata->oovd_notif;
        stat->errors      = rdata->oovd_err;
    }

    /* Clear the sub-IRQ status */
    regmap_write(d->regmap, BD957X_REG_INT_OVD_STAT,
                 OVD_IRQ_VALID_MASK & val);

    return 0;
}
```


Example helper registration

```
struct regulator_dev *rdevs[BD9576_NUM_REGULATORS];

rdevs[i] = r->rdev;
if (i < BD957X_VOUTS1)
    ovd_devs[i] = r->rdev;

r->rdev = devm_regulator_register(&pdev->dev, desc, &config);

// snip

int ovd_errs = REGULATOR_ERROR_OVER_VOLTAGE_WARN | REGULATOR_ERROR_REGULATION_OUT;

ret = devm_regulator_irq_helper(&pdev->dev, &bd9576_notif_ovd, irq, 0, ovd_errs, NULL,
                                &ovd_devs[0], BD9576_NUM_OVD_REGULATORS);
```

No answers promised :)

Questions?

That's all peeps!

Thank You!