Intelligent Power Supply Design

Adding a Microcontroller to a power supply design and what it will do for the design.
System Level Design Flow

● Requirements Analysis
● Dividing up the Design
  ● Analog Functions: Topologies, Feedback, and Safety
  ● Microcontroller Functions: Control, Monitoring, and communications
  ● Software Functions: Control, Reporting, Deterministic and Self Correcting functions
● Choosing Components
Analyzing the Design Requirements
Requirements analysis

- Analog performance specifications
  Input and output Voltage, Current, Power, Accuracy, Temperature stability, and safety

- Digital performance specifications
  - Controls; resolution, accuracy, and timing
  - Signal monitoring and storage requirements
  - Communications speed and format

- Software based functions
  - Behavior, resolution, and timing
Dividing up the Design

Analog
Digital
and Software
Generate the system level Analog Design

- System level analog design based on analog performance specifications:
  - Topology: Boost, Forward, Flyback
  - Voltage Mode / Current Mode
  - Continuous / Discontinuous inductor current
  - Determine Switching Frequency, Inductor, and filter capacitor
  - Feedback Compensation
  - Any additional analog functions
Generate the system level Digital Design

- Determine Level of Integration to meet requirements
  - Level1: Augmenting a Standard Analog design
  - Level2: Controlling a Standard Analog design
  - Level3: Reconfiguring a Standard Analog design
  - Level4: Replacing a Standard Analog design
Level 1 Integration

- Augmenting a stand-alone analog design
  - Adding limited on/off control functions; soft-start, start-up sequencing, auto shutdown.
  - Adding monitoring functions; data logging, input/output reporting, fault detect.
Level 2 Integration

- Controlling a stand-alone analog design.
  - In addition to All Level 1 control features; Output voltage, current limit, switching frequency, and max duty cycle control.
- Still traditional stand-alone analog design.
Level 3 Integration

- Reconfiguring a stand-alone analog design.
  - All Level 1 and 2 features.
  - Change analog loop configuration.
  - Swap between different loop filters.
- Still Traditional stand-alone analog design.
Level 4 Integration

- Replacing a stand-alone analog design.
  - All Level 1, 2, and 3 features
  - Programmable DSP loop filter control
  - Loop acquisition aids and non-linear responses
  - A completely Digital design.
Define Software Functions

- Deterministic Functions
  - Generating a sequence of events
    - Softstart, startup sequencing, restart on error
  - Recognizing a sequence of events
    - Predicting Failures, advance power down, Data logging, Retry limits.

- Remote control functions
  - Output voltage, current limit, shutdown, sequencing, coordinated actions
Define Software Functions

- **Remote Reporting functions**
  - Current voltage, current, temperature
  - Calculated values such as power and efficiency

- **Self correcting functions**
  - Temperature compensation of Vref
  - Calibrated output Value
  - Temperature driven current limits
  - Current driven feedback selection
Component Selection

Microcontroller, Analog and Software
Choosing Microcontroller Peripherals by Level

- **Control**
  - **Level1**: Digital I/O for on/off control
  - **Level2**: PWM for control voltages/timing
  - **Level3**: Switching comparators, amps, muxes
  - **Level4**: High resolution PWM for switching with emergency shutdown via comparator

- **Monitoring**
  - **Level1-3**: ADC and comparators
  - **Level4**: Fast, high resolution ADC
Additional Microcontroller needs

- Communications
  - I2C™, SPI™, Microwire, RS-232, CAN
  - Single line controls for faster controls
- Fast multiply capability for Level4 PID implementation
- Non-volatile storage for configuration and data logging
- Safety features, Watch dog timer, Brown out Reset, Low Voltage Detection, oscillator fault
Analog Connectivity

The Microcontroller’s impact on the analog design
Level 1 Analog Connectivity

On/Off control of the PWM

Monitoring Temperature

Monitoring Verror

Monitoring Voutput
Level 2 Analog Connectivity

Monitoring the Voltage reference

On/Off control of the PWM

Limiting Verror

Supplying Scaled Vref

Output

Status

Microcontroller

PWM

VREF

Monitoring Voutput

Voutput
Level 3 Analog Connectivity

On/Off control of the PWM

Multiplexing Alternate Feedback paths

Monitoring Verror

Generating Vref

Monitoring Voutput
Level 4 Analog connectivity

Full duty-cycle control of PWM

Microcontroller ➔ PWM ➔ Output

ADC ➔ Monitoring Voutput ➔ Status
Software components

Deterministic, self correcting, and communications functions and features
Software

- Deterministic functions
  - Timer interrupt driven State machines for generating and responding to sequential events.

- Self Correcting functions
  - ADC driven routines for adjusting output voltage and current limit

- Communications, sending and receiving
  - Communications Interrupt driven routines

- One central software loop to call to handle setup and any other functions
Software

- Timer Interrupt
- Fault State machine
- Soft Start State machine

- ADC Interrupt
- Auto Correction
- Calibration

- USART Interrupt
- Receive Commands
- Send Status

- RESET
  - Setup
  - Other Functions

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Additional Resources

- TB081  Soft-start controller for Switching Power supplies
- AN258  Low-Cost USB Microcontroller Programmer
- TB053  Generating high voltage using the PIC16C781/782
- AN540  Implementing IIR filters
- TB085  A simple circuit for driving microcontroller friendly PWM generators
- AN32   CMOS SMPS current mode controller
- AN936  Implementing a PIC® controller using a PIC18 MCU
- AN216  DC-DC converter controller using a PIC® MCU
- AN823  Analog design in a digital world using mixed-signal controllers
- DS51308 PICDEM™ MSC1 SMPS Daughter Board Users Guide
- Web Seminar Archive: Developing Intelligent Power Systems using the MCP1630 High Speed PWM
Conclusion

- Intelligent power supply design is a fusion of Analog, Digital, and Software.
- The level of integration determines:
  - Possible features
  - Microcontroller peripheral needs
  - Required analog connectivity
- Software implements:
  - Deterministic and Self Correcting functions, remote control and reporting