APPLICATION NOTE

ABSTRACT
The supply voltages of microcontroller systems go through unspecified ranges when the system is switched on or off, or when the power is not stable for any other reason. This application note describes methods to protect the system against unwanted behaviour.

AN468
Protecting Microcontroller Systems against Power-Supply Imperfections

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INTRODUCTION

In normal operation, microcontrollers are sourced by a regulated and somehow stabilized power supply. This power supply ensures a supply voltage to the microcontroller, which lies in the range of the micro-controller's specification. Under certain conditions however, the power supply may not be able to keep up the required voltage.

This may be e.g. during extended complete power failures ("blackouts") or insufficient power levels ("brownouts"). After powering the system up it takes some time before the supply voltage is stable. When it is switched off again the voltage follows an unpredictable curve down to zero volts.

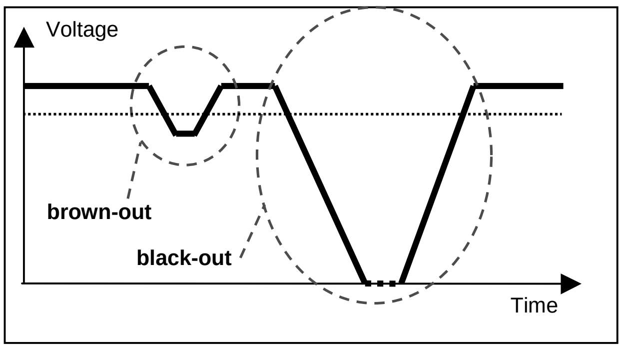

Figure 1 Blackout and Brownout

Whenever in such cases the supply voltage is below the minimum specified level, the microcontroller's behaviour cannot be predicted, which can lead to critical situations of the application.

Unwanted effects are:

- wrong execution of the application program,
- outputs changing state,
- unintended accesses to internal or external memory.

This report provides some hints how a system can be protected against unwanted effects.

MICROCONTROLLER RESET

The behaviour of most microcontrollers can be controlled even below the operational supply voltage range by activating the reset input. It is common practice to connect the reset input to a RC-combination, which is directly connected to the power supply. This ensures that the microcontroller does not start to work before the supply voltage is stable for a certain time and the oscillator could start up. This is sufficient for many applications.

In systems, where write-accesses to non-volatile memories, like EEPROM and Flash, or uncontrolled output states must be avoided, additional measures have to be taken at least for the turning-off of the supply.

BROWNOUT DETECTORS

There are circuits available that monitor the actual supply voltage of a system incorporating an internal voltage reference. These brownout detectors (BOD or system reset ICs) can trigger an event whenever

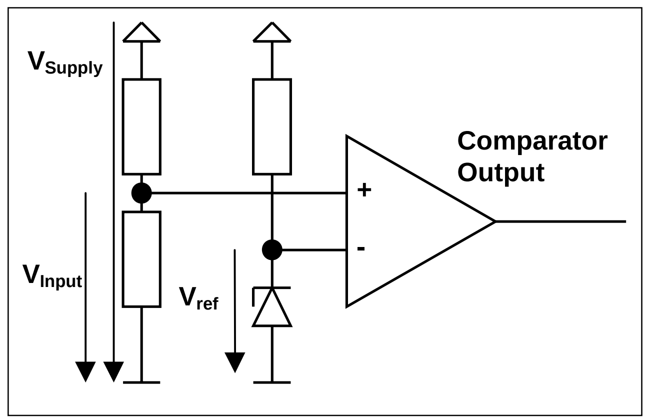

Figure 2 Brownout Detector Principle

the supply voltage drops[1] below a defined level. The voltage level triggering the event is the trip-voltage. In the simplified circuit of figure 2, the trip voltage is equal to the reference voltage. To avoid oscillating of the output at very slow ramps of the supply voltage, different trip-levels (hysteresis) should be used for rising and falling edge.

If the output of the comparator is directly connected to the reset input of the microcontroller, a basic system protection is achieved. In many cases however, it is desirable to take some controlled action before the power fails completely and the system is stopped. This can be obtained by issuing a power-fail signal as an interrupt to the microcontroller at a certain time before the reset is activated.

[1] This report assumes the power supply is capable of suppressing over-voltage spikes etc.

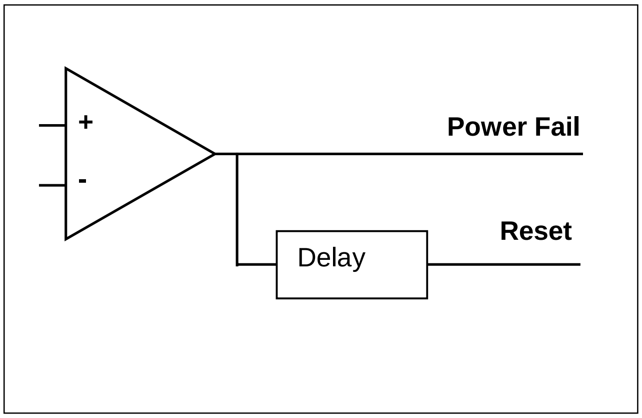

Figure 3 Power Fail Signal ...

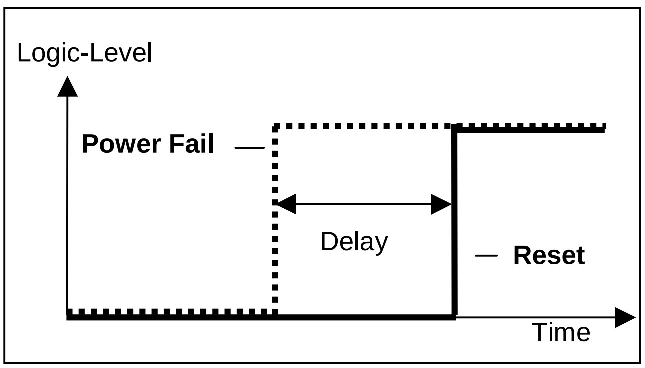

Figure 4 ... with Delayed Reset

A good way to detect a waning power supply is to sense the unregulated supply voltage. Some brown-out detectors offer an input to a second comparator, which can be connected (via a voltage divider) to the

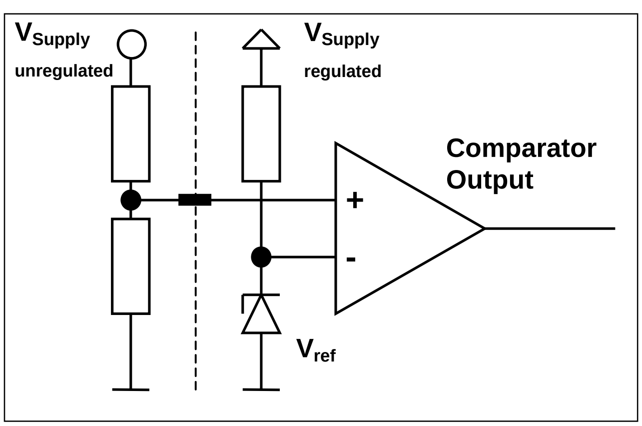

Figure 5 2nd comparator to detect brownout

unregulated power supply. In this way, the power fail signal can interrupt the processor from executing its "normal" routines. Before the voltage drops below a critical level, which cannot be adjusted by the voltage regulator supplying the microcontroller, there is enough time to save vital data in a non-volatile memory, for output signals to close valves etc. Finally, the microcontroller is stopped by the reset signal. The length of the interval available for emergency actions depends on the charge stored on capacitors on the unregulated side of the power supply.

EXAMPLES

Integrated Brownout Detectors

Several companies offer brownout detector ICs or system reset ICs in many variants. They vary e.g. in the following features:

- trip voltage (broad range of fixed values from below 2V to above 5V or variable)
- Hysteresis
- power fail output and delayed reset output
- programmable timings (delays)
- output configuration: push-pull, open drain or collector
- output(s) active high or low
- packages: SMD, DIP, transistor packages

Type	Trip Voltage	Output Config. 1)	Logic Level
Philips SA56614-47	4.7V ± 2%	push pull	active low
Mitsumi PST3345	4.5V ± 2%	push pull	active low
Mitsumi PST3247	4.7V ± 2%	open drain	active low
Maxim MAX6807UR26-T	2.6V ± 2%	push pull	active high
Philips PCF1252-0T	4.75V ± 1%	push-pull	selectable

Application Examples

Many microcontrollers today have on-chip brownout detectors, particularly Flash microcontrollers that operate from a single power supply. These controllers generate the high voltages required for erasing and programming of the Flash memory on-chip. The brownout detection keeps them from unintentionally destroying the memory contents.

Early versions of the Philips 16-bit Flash micro-controller XA-G49 did not have an on-chip BOD. The

XA-G49 was chosen for the following examples to illustrate the use of external brownout detectors.

Simple Brown-Out Detection

A CMOS system reset IC with open drain output is used as a simple brownout detector (figure 6). Three connections to the system are used: GND, V_{DD} and OUT. OUT can be connected directly to the RESETN-input of the XAG49.

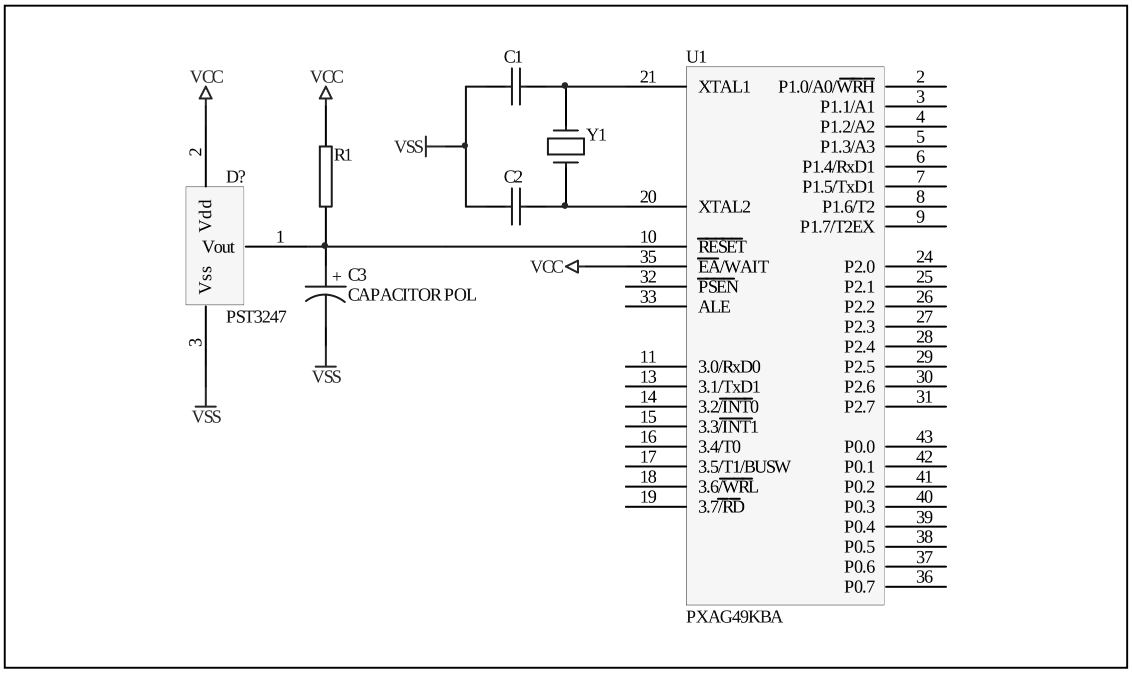

Figure 6 Simple Brownout Detector

When power is turned on and V_{DD} reaches its nominal value, the output enters a high-impedance state. This starts the normal power-on reset delay, which is defined by the RC-combination connected to the RESETN input of the microcontroller.

When the power supply voltage drops below the trip voltage, the output of the brownout detector IC goes low and the microcontroller is reset. The trip voltage was chosen in such a way, that this happens while the supply voltage is still within the limits of the microcontroller's specified range.

Brownout Detection with Power-Fail Interrupt

More complex power supply supervisions can be achieved with Philips' PCF1252-X family (figure 7). Again the power supply voltage is monitored against a precise voltage reference. If it falls below the trip voltage, a power fail interrupt is requested by the signal POWFN connected to INT0 of the microcontroller. After a programmable delay time, a reset signal RESET becomes active. The polarity of this signal can be selected with a pin to be high or low. The XA-G49 e.g. requires an active low signal at RESETN. The duration of the delay is set with a capacitor. This also determines the length of the power-on reset for the system.

The PCF1252-X has a second comparator as described above to also monitor the unregulated power supply. A second trip level above the regulated supply voltage can be set with a voltage divider. The output COMOUT triggers an additional interrupt (INT1N). This interrupt appears long before the regulated supply is affected and can be used e.g. to signal a failing power supply to a remote system.

A sample code for such a system is listed below. Both interrupts are initialized for falling edge activation. With failing power, INT1 is triggered first. The interrupt service routine sends an alarm message e.g. via the UART as an early warning to a supervising system.

If the power continues to fail, the regulator cannot keep up the supply voltage required by the system. This activates INT0 and, in parallel, starts the delay cycle for the reset signal. The INT0 service routine now has at least 100µs to store e.g. vital information in a non volatile memory etc. When this is done the microcontroller is put in power-down mode, which freezes the system by stopping the oscillator. Next, the PCF1252-0 forces the reset signal low until the supply voltage drops to an uncritical level (below 1V).

Reset timings are defined by the chosen capacitor value, which is 15nF in this example. This equals to a typical power-on reset time of 15ms for the oscillator to start up, which ensures the required 10ms as worst case for all tolerances. In the power failure case this capacitor value gives 150µs delay for the reset signal.

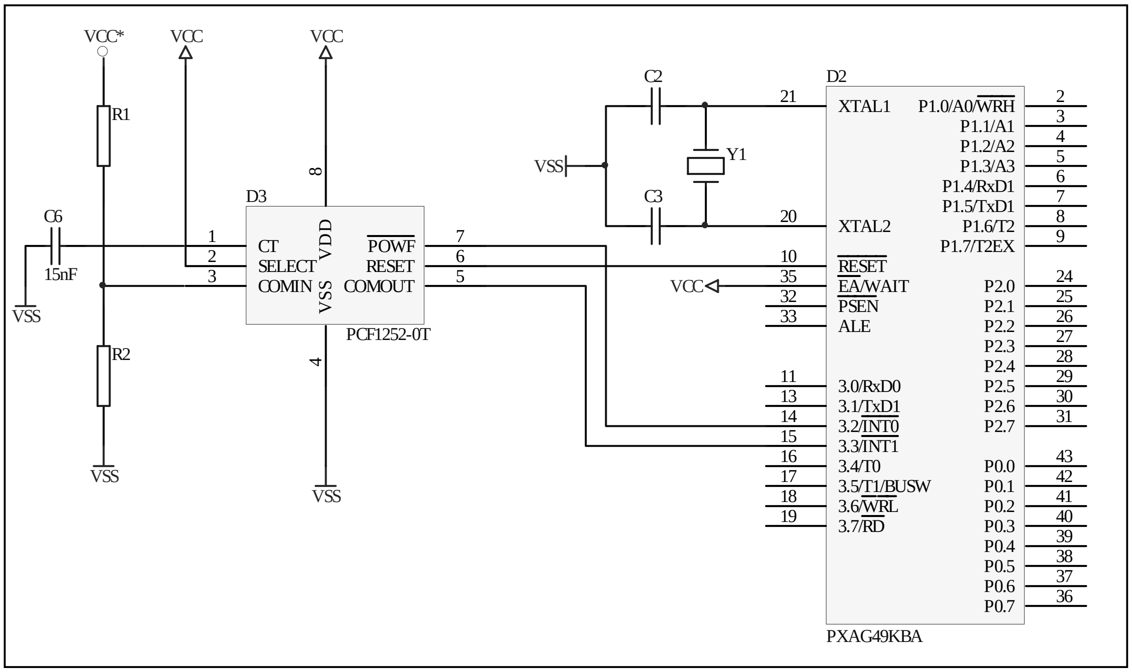

Figure 7 Brownout Detector with Power Fail Signal and Second Comparator

```
void PwrFailInt() interrupt 0
 {
  //Insert your code here
  //e.g. SaveData("Save vital information in non-volatile memory");
  AUXR|=0x40;
  PCON|=0x02; // Power-Down Mode
  //PCON|=0x01; //Idle Mode
  IE0=0;
  return;
 }

void ComoutInt() interrupt 2
 {
  //Insert your code here
  //e.g. SendAlarmMsg("Supply Voltage Failure");
  IE1=0;
  return;
 }

 void InitPwrFailInt()
 {
  P3CFGB|=0x04; //Int0-Pin to Input-Mode (High-Impedance)
  P3CFGA&=0xfb; // ""
  IT0=1;        // Sensitivity to transistion
  IPA0&=0xf0;   // Set Priority
  IPA0|=0x02;             //   ""
  EX0=1;        // Enable external Int0
  EA=1;         // Enable all Int
  return;
 }

 void InitComoutInt()
 {
  P3CFGB|=0x08; //Int1-Pin to Input-Mode (High-Impedance)
  P3CFGA&=0xf7; // ""
  IT1=1;        // Sensitivity to transistion
  IPA1&=0xf0;   // Set Priority
  IPA1|=0x02;             //   ""
  EX1=1;        // Enable external Int1
  EA=1;         // Enable all Int
  return;
 }
```

REFERENCES

For further details please refer to the following publications:

- Philips Datasheets: www.semiconductors.philips.com
- Datasheet SA56614-XX: SA56614-XX; CMOS system reset; Product data 2001 Apr 24
- Datasheet PCF1252-X: PCF1252-X family; Threshold detector and reset generator; Product specification 1998 Apr 16
- Datasheet PXAG49: XA-G49; XA 16-bit microcontroller family; Preliminary specification 2000 Dec 01
- Datasheet Mitsumi PST3345, PST3247: CMOS System Reset; Monolithic IC PST31XX~34XX Series
- Datasheet Maxim MAX6807UR26: MAXIM Voltage Detectors; Rev. 1; 4/99 MAX6806/MAX6807/MAX6808

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Definitions

Short-form specification – The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information, see the relevant datasheet or data handbook.

Limiting values definition – Limiting values given are in accordance with the Absolute Maximum Rating System (IEC134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.

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