# APPLICATION NOTE

**ABSTRACT**
This application note describes the power supply of a P89LPC900 microcontroller from a single cell for low power applications like hand held devices.

# AN10218
# Philips LPC900 microcontrollers single cell power supply

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## INTRODUCTION

This application note describes the power supply of a P89LPC900 microcontroller from a single cell for low power applications like hand held devices.

The LPC900 are low power microcontrollers with a supply voltage range from 2.4 V to 3.6 V. The supply current varies from below 1 µA in total power down mode, over some 10 µA with low speed oscillator to several mA at high speed. The current that is sourced from the I/O pins is additional and has to be taken into account. In applications that are often in low power mode like hand held devices the average current is very low and the battery life can reach several month.

This application note describes an easy, low cost solution of a capacitive step up DC–DC converter to create the supply voltage from a single cell with a voltage from 1.2 V to 1.5 V.

A Philips quad 2–input NAND Schmitt–Trigger 74LV132 is used to generate the supply voltage.

The 74LV132 has a wide operation voltage range from 1.0 V to 5.5 V and is optimized for low voltage operations from 1.0 V to 3.6 V. This range is ideally suited to operate from a single cell.

One Schmitt–Trigger NAND gate is used to build a multivibrator/oscillator with a resistor and a capacitor (see figure 2).

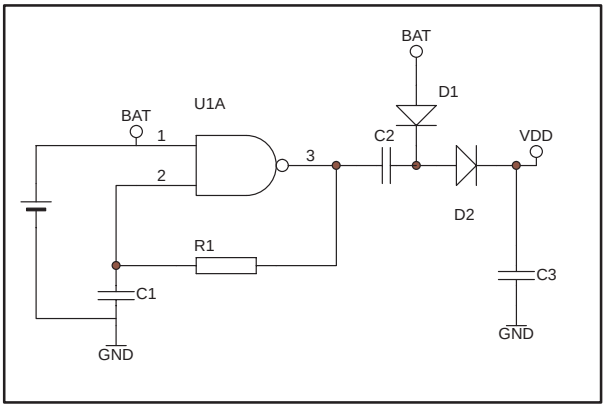


**Figure 1. Single cell power supply**

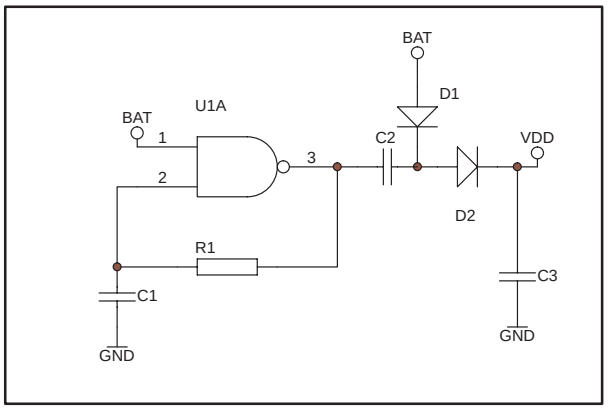


**Figure 2. Voltage Doubler**

The square wave output is connected to a voltage doubler with D1, D2, C2 and the output voltage at C3. The principle can be extended to higher voltages.

With an extra inverter it is also possible to build a Dickson charge pump, e.g. as a voltage tripler (see figure 3).

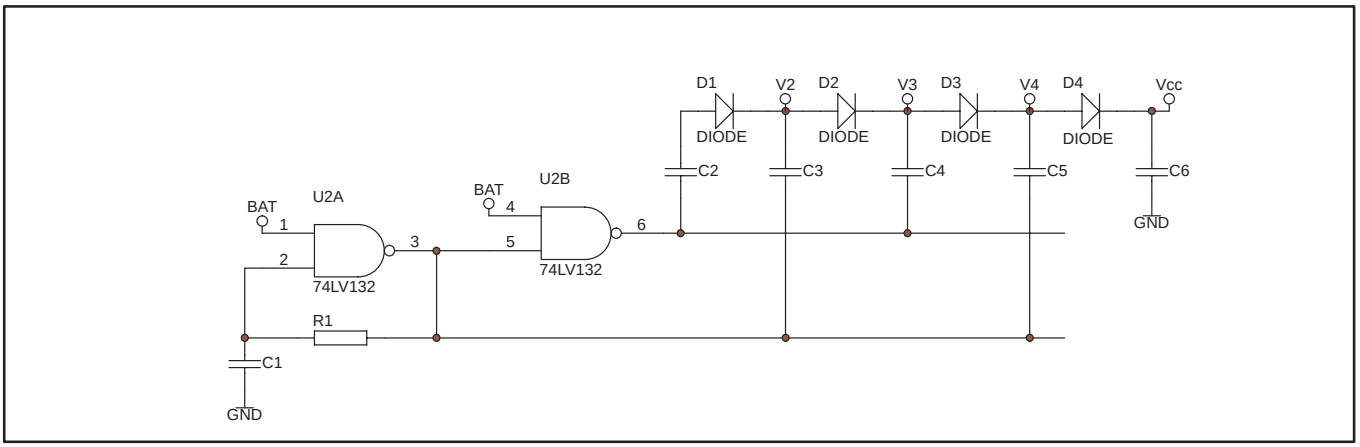


**Figure 3. Dickson Charge Pump**

The output voltage is approximately:

$$V_{DD} = n \times (V_{Batt} - V_{Diode})$$

For best efficiency it is recommended to use diodes with low voltage drop like the Philips BAT54 schottky diodes. The specified voltage drop at 10 mA is maximal 320 mV. The voltage tripler would generate a $V_{DD}$ of about 3 V. It is also possible to use a voltage quadrupler for a higher $V_{DD}$, but then the microcontroller must be protected against voltages above maximum rating.

Figure 4 shows a complete application with an LPC932 driving a LED.

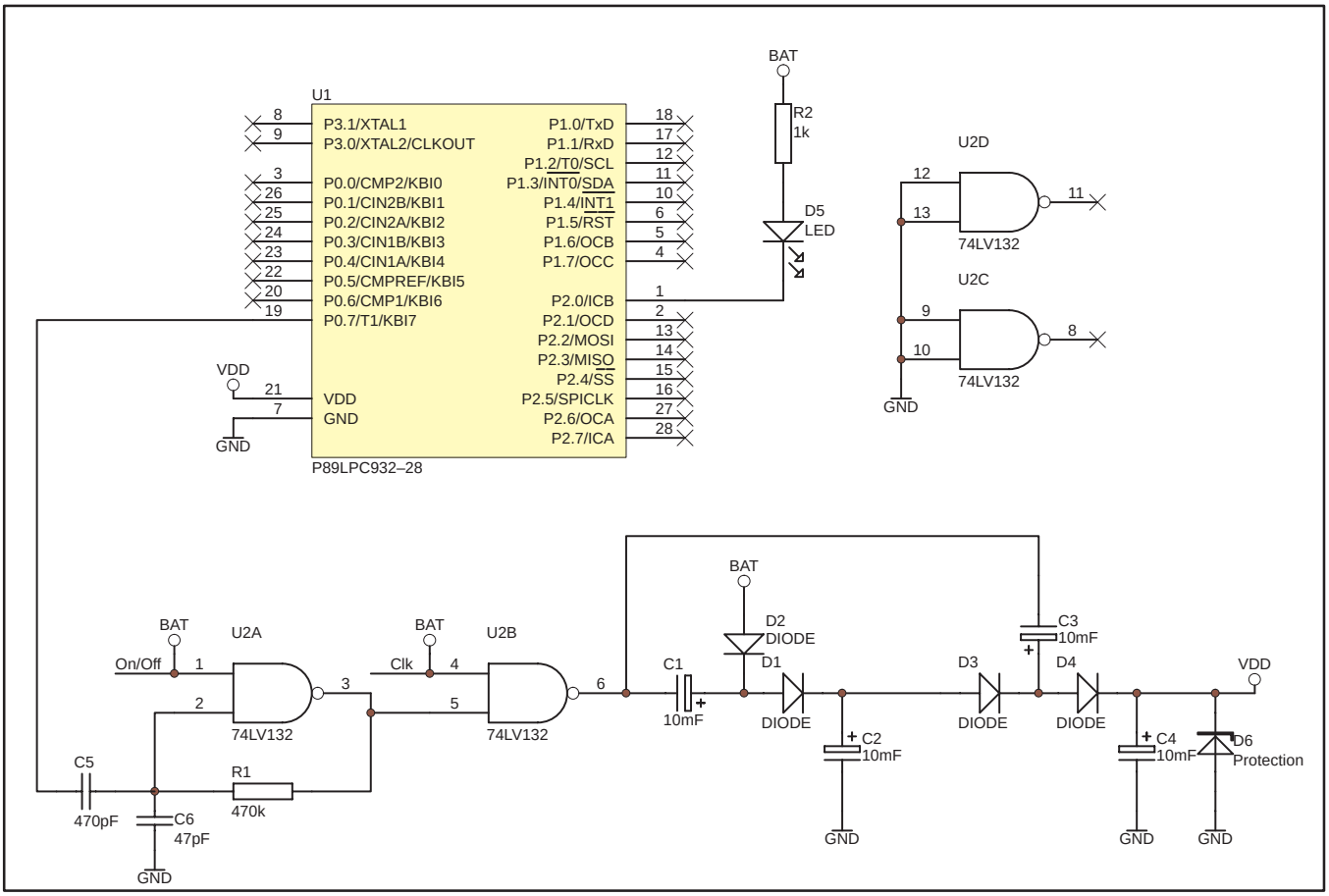


**Figure 4.**

## Example

This is an application example where the LPC900 switches to total power down and can be woken up by an external interrupt. The interrupt routine flashes an LED and puts the LPC900 back into total power down.

The power consumption of the LPC932 in ‘total power down’ can be below 1 μA, depending on configuration and supply voltage.

Special care must be taken to switch off all unnecessary functions, e.g., watchdog oscillator or analogue functions.

With the configuration in figure 4 we reached total power consumption below 20 μA for the whole circuit. To reach a high dynamic between low power state and high current source capability in active mode the LPC932 can switch the oscillator frequency on demand. This is done with P0.7 and C5. In low power mode P0.7 is driven low and C5 adds to the time constant and reduces the oscillator frequency and therefore the current consumption. In active state P0.7 is switched to input mode and the oscillator speeds up and can source more current into the application. The current consumption and capability can be switched from below 20 μA to several mA.

For higher currents the capacity of C1 to C4 can be increased and the oscillator frequency can be raised (even in the MHz range).

For better load regulation it is also possible to drive the voltage multiplier with a frequency from the LPC932. A port pin connected to pin 1 (On/Off) of the NAND gate can switch off the oscillator and a PWM signal from the LPC932 (e.g. from a timer) connected to pin 4 (Clk) drives the multiplier.

The following code is a simple demonstration of the average low power consumption. The watchdog oscillator is used and all unnecessary peripherals are switched off.

The software configures the LPC, initializes the keyboard interrupt, flashes the LED at port 2 and enters total power down mode.

If P0.5 is pulled low the keyboard interrupt wakes up the LPC, accelerates the RC–oscillator and the LED is flashed before the LPC900 re–enters total power down mode.

```
/*=========================================*/
/*
;     SOURCE_FILE:     main.c
;     APPLICATION:     P89LPC932
;                      Single Cell Demo
;     ORIGINAL AUTHOR: Torsten Eggers
;     PS BLM-Hamburg
;     VERSION:         1.0
;     DATE:            2003/03/01
;
;     (C) 2003: Philips
/*=========================================*/

#include <Reg932.h>

unsigned int   i,loop;
unsigned char  off;

void keypad_init(void)
{
  // P0.5 must be pulled high
  KBPATN = 0x20;
  // P0 must match KBPATN to generate interrupt
  KBCON = 0x02;
  // mask out all pins except P0.5
  KBMASK = 0x20;
  // enable keypad interrupt
  EKBI = 1;
  // enable interrupts
  EA = 1;
}

void keypad_isr(void) interrupt 7 using 1
{
  P1M2 = 0xFC;//fast Oscillator
  //turn on peripherals
  PCONA = 0x00;

  // flash P2
  for(loop=0;loop<5;loop++)
   {
   P2 = 0xFF; //turn off P2 (LED)
   for(i=0;i<10000;i++){}
   P2 = 0x00; //turn on P2 (LED)
   for(i=0;i<1000;i++){}
   }

  // turn off P2 (LED)
  P2 = 0xFF;

  //clear KBIF by writing 0 to it
  KBCON &= 0xFE;
  off = 1; //power down flag
  }
```

```
void main(void)
{
  // configure Ports
  P0M1 = 0x20;
  P0M2 = 0xDF;
  P1M1 = 0x03;//P1.3 Input
  P1M2 = 0xFC;
  P2M1 = 0x00;
  P2M2 = 0xFF;
  P2M1 = 0x00;
  P2M2 = 0xFF;
  P3M1 = 0x00;
  P3M2 = 0xFF;

  P0=0xFC;
  P1=0xFC;
  P2=0xFF;
  P3=0xFF;

  // flash P2
  for(loop=0;loop<4;loop++)
   {
   P2 = 0xFF; // turn off P2 (LED)
   for(i=0;i<10000;i++){}
   P2 = 0x00; // turn on P2 (LED)
   for(i=0;i<100;i++){}
   }
  // turn off P2 (LED
  P2 = 0xFF

  IEN1 = 0xE8;
  EKBI = IEN1^1;

  keypad_init();

  AUXR1 = AUXR1|0x80; //Set CLKLP Low Power Clk
  WDCON = WDCON&0xFE; //WDOsci off

  //turn off peripherals that can be turned off
  PCONA = 0xEF;
  P1M2 = 0xFF;//slow Oscillator

  //switch to idle mode
  //PCON |= 0x03;// total power down

  while(1)
  {
  if (off) //power down flag
   {
   off = 0;
  //turn off peripherals that can be turned off
  PCONA = 0xEF;
  // switch to total power down
  P1M2 = 0xFF;//slow Oscillator
  PCON |= 0x03;// total power down
   };
  }
}
```

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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 data sheet or data handbook.

**Limiting values definition —** Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). 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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