Application Report
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Simple 1.5-V Boost Converter for MSP430

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ABSTRACT

A simple, efficient, low-cost, boost converter to take 1.5 V from a single type-AA alkaline battery to the operating voltage required by the MSP430 family of ultralow-power microcontrollers is described. Expected battery life is up to 1000 hours.

Contents

List of Figures

List of Tables

1 DC to DC Conversion

Technically, dc-to-dc conversion is stepping up or stepping down one level of dc voltage to another. Here, the concern is with a step-up converter, also known as a boost converter.

1.1 Functional Description

Figure 1 shows the complete schematic of the circuit employed for the dc-to-dc converter. Transistors Q1 and Q2 form a square-wave astable multivibrator oscillator. Any bipolar silicon transistor with a minimum current gain of 100 can be used for Q1 to Q4. The square wave oscillator scheme starts reliably even at 0.8 V. To avoid the rectifier section loading the oscillator and to provide enough current drive to the load, a buffer amplifier is introduced between the rectifier and the oscillator. Transistors Q3 and Q4 act as buffers; they are connected in a push-pull configuration to ensure equal current drive during on and off times.

There is a crossover voltage of roughly 0.6 V, which helps to avoid high-impulse current flow during transition at the square wave edges. This crossover inherently provides a dead-band of 0.6 V for the buffer stage, thus simplifying the design.

The output of the buffer is passed through an efficient rectifier circuit designed around two capacitors and two diodes. Germanium diodes are employed here because they have a lower voltage drop—only 0.3 V compared to 0.7 V for Silicon junction diodes. Schottky diodes can be used instead, but they are considerably more expensive than germanium diodes. The final capacitor is the charge reservoir capacitor, and the accumulated negative voltage is added with the 1.5 V of the battery to get an output of around 3.0 V dc.

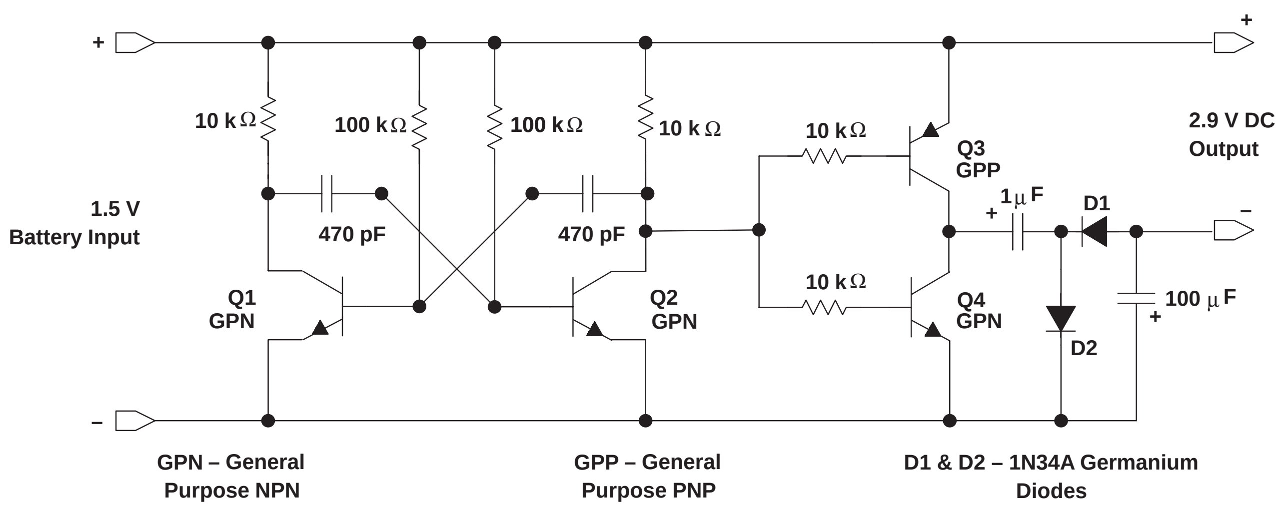

Figure 1. Schematic of the DC-to-DC Converter

The no-load current of the converter is around 300 μA and the frequency of operation is determined by the RC time constant of the base-collector feedback network of the oscillator. The operating frequency is approximately *Fosc = 0.8/RC*, where *R* and *C* are the values of the base resistor and the collector-to-base-feedback capacitor, respectively.

1.2 Running the MSP430 With the DC-to-DC Converter

The boost converter makes it possible to operate an MSP430 using only a single 1.5-V Type-AA or Type-AAA battery. A good example consists of the simple set up with the MSP430F1121 shown in Figure 2. Reference [1] is the data sheet for this device.

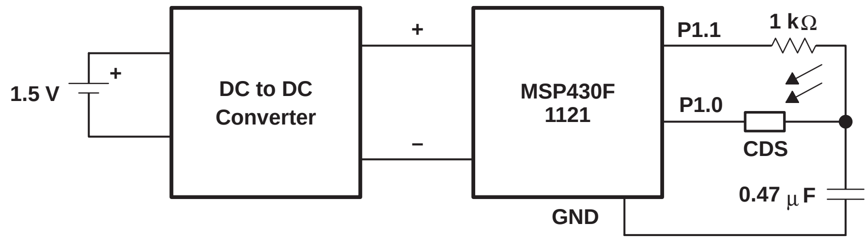

Figure 2. MSP430 With a Single 1.5-V Battery

A CDS type of light sensor is connected to the comparator input, which is referenced internally with 0.25 x Vcc. The light sensor has a resistance of 200 kΩ in the dark and around 5 kΩ in ambient light. The logic is as follows.

The MSP430 reads the resistance of the CDS light sensor with a scheme built around TimerA and one of the capture registers. To make it simple, a 470-nF capacitor is charged via a 1 kΩ resistor and discharged through the CDS sensor. The discharge time is tracked with TimerA and a capture register, and the captured 16-bit number equivalent to light brightness is stored in register R14. This register is then used in a delay loop which sets the on time for a flashing LED, causing the LED to flash with a lower duty-cycle and faster frequency in ambient light and to become brighter and flash slower as the sensor receives less light. The Assembler code that meets this functionality is given in Appendix A.

This simple setup demonstrates the ability of the MSP430 and its peripherals to operate on just a single 1.5-V battery. The remaining question is how long the battery will last.

1.3 Battery Life

The parameters listed in Table 1 give a good indication of the expected life of a Type-AA 1.5-V battery in such a prototype circuit.

Table 1. System Operating Parameters

V_{in}	I_{in}	F_{osc}	I_{load}	V_{out}
1.5 V	300 µA	17 kHz	0	2.9 V
1.5 V	2 mA	17 kHz	1.6 mA, MSP430 & LED connected, LED ON	2.3 V
1.2 V	1 mA	16 kHz	0.6 mA,MSP430 & LED connected, LED Flashing	1.8 V
1.5 V	500 µA	17 kHz	MSP430 running NO LED	2.8 V

Using a type-AA alkaline battery (with an amp-hr capacity of 0.5 Ah), the data shown in Table 1 indicate that this system with just the MSP430 microcontroller running (no LED connected) would run for approximately 1000 hours.

In this example the microcontroller does not sleep; timer-A keeps running, the port pin remains active, and the comparator stays on. Even longer battery life could be achieved by using MSP430 low-power modes.

2 Reference

1. MSP430x11x1 Mixed Signal Microcontroller, data sheet, Texas Instruments Literature Number SLAS241C.

Appendix A Assembler Code

```
#include     ”msp430x11x1.h”                  ; Standard Equations
;*************************************************************************************
;    MSP430F1121 Demonstration Program - Light Sensor
;
;    Murugavel Raju
;    Texas Instruments, Inc
;    July 2000
;*************************************************************************************
NAME         IntelligentLightSensor
;*************************************************************************************
             RSEG  CSTACK
             DS    0

             RSEG CODE
main
RESET        mov     #SFE(CSTACK),SP          ; define stack-pointer
             call    #Init_Sys                ; Initialize sytem
Mainloop     call    #measureLDR              ;
             bis.b   #002h,&P2OUT             ; set P2.1
Wait1                                         ;
L1           dec     R14                      ; Decrement R15
             jnz     L1                       ; Delay over?
             bic.b   #002h,&P2OUT             ; reset P2.1
Wait2        mov     #30000,R15               ; Delay to R15
L2           dec     R15                      ; Decrement R15
             jnz     L2                       ; Delay over?
             jmp     Mainloop                 ; Repeat

;*************************************************************************************
Init_Sys     ; Initialize system
;*************************************************************************************
             mov     #WDTPW+WDTHOLD,&WDTCTL   ; Stop WDT
SetupP1      mov.b   #000h,&P1OUT             ; Reset port1 out register
             mov.b   #0fch,&P1DIR             ; unused port pins as outputs
                                              ; for low current operation
                                              ; P1.0 & 1.1 as inputs
SetupP2      mov.b   #000h,&P2OUT             ; Reset port2 out register
             bis.b   #0f7h,&P2DIR             ; P2.1 as LED o/p and other
                                              ; P2.X as outputs for low current
```

```
                                        ; P2.3 as input
          bis.b   #00Ch,&P2SEL          ; P2.3 as comparator NI input CA0
          ret

;*********************************************************************************
measureLDR   ; LDR resistor measurement SBR
;*********************************************************************************

          mov.b   #CARSEL+CAREF0+CAON,&CACTL1
                                        ; Define comp_A mode
          mov.b   #P2CA0+CAF,&CACTL2    ; Connect CA0 to noninv.
                                        ; i/p of comparator
SetupTA   bis     #TASSEL_1+TACLR,&TACTL ; TimerA to count SMCLK
SetipCCR1 bis     #CM1+CCIS0+CAP,&CCTL1 ; CCR1 set to capture when
                                        ; comparator out goes low
          bis.b   #02h,&P1DIR           ; Charge cap pin as output
          bis.b   #02h,&P1OUT           ; Charge cap
          call    #delay                ; Give enough time for charging
          bic.b   #02h,&P1DIR           ; P1.1 to high-impedance to hold
                                        ; charge
          bis     #MC1,&TACTL           ; Start TimerA to count all 16bits
          bis.b   #01h,&P1DIR           ; P1.0 to ground to discharge cap
loopCALO  bit     #CCIFG,&CCTL1         ; Check if comparator goes low
          jz      loopCALO
          mov     &CCR1,R14             ; Store CCR1 value in R14 count
                                        ; equivalent to discharge time
          bic.b   #01h,&P1DIR           ; P1.0 reset as input
          bic.b   #02h,&P1DIR           ; P1.1 output low
          mov     #0h,&CCTL1            ; Reset CCR1
          mov     #0h,&TACTL            ; Disable timer
          mov.b   #0h,&CACTL1           ; Disable comparator
          mov.b   #0h,&CACTL2           ;
          ret
;*********************************************************************************
delay        ; Software delay loop to ensure capacitor fully charged
;*********************************************************************************
          push    #099h                 ; Delay to TOS
DL1       dec     0(SP)                 ; Decrement TOS
          jnz     DL1                   ; Delay over?
          incd    SP                    ; Clean TOS
          ret                           ;
```

```
;***********************************************************************************
            COMMON  INTVEC                         ; MSP430x11x1 Interrupt
                                                   ; vectors
;***********************************************************************************

            ORG     RESET_VECTOR
RESET_VEC   DW      RESET                          ; POR, ext. Reset, Watchdog
            END
```

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