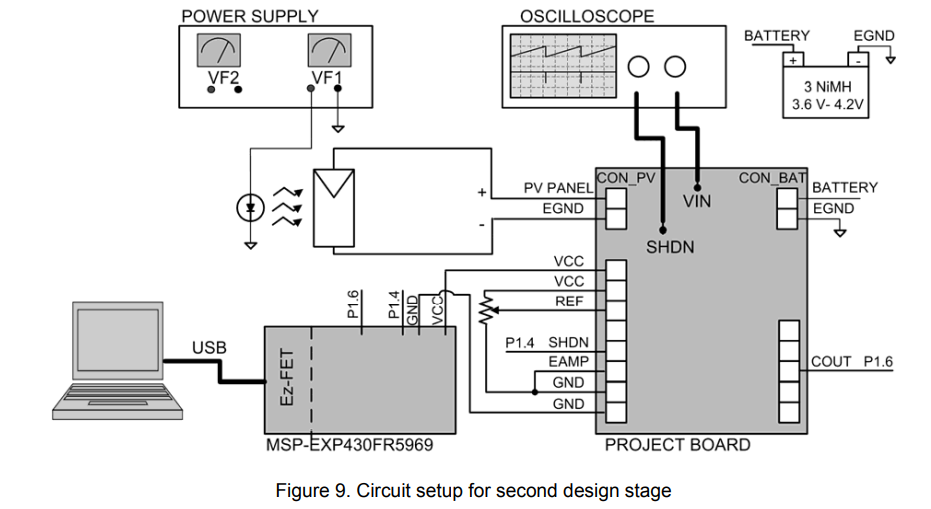
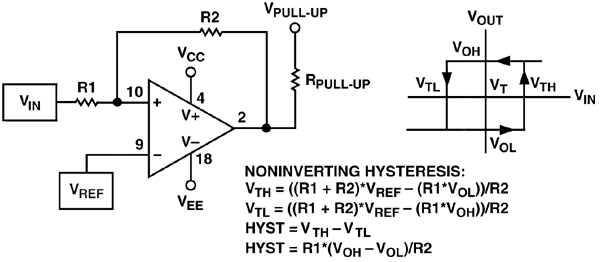
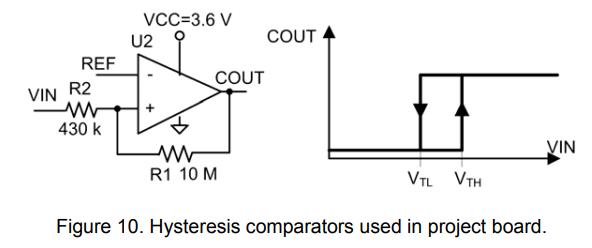
4. PULSE FREQUENCY MODULATION FOR A FIXED BIAS VOLTAGE The second design stage consists on controlling SHDN terminal to hold the bias voltage of input capacitor (VIN) into a hysteresis band gap. 4.1 Use the project board, MSP-EXPFR5969 and PV panels to build the circuit of Fig.9.



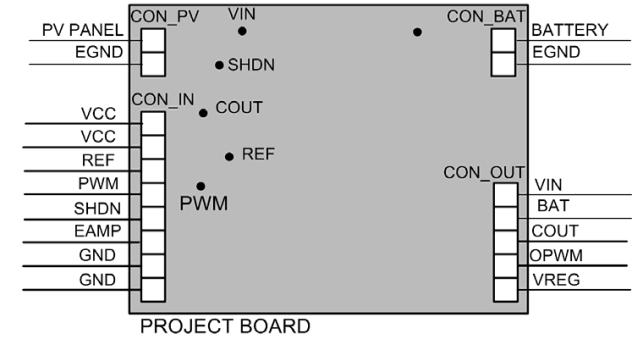
4.2 A potentiometer is used in this stage to set the value of REF. Analyse the circuit of Fig.10 and calculate the threshold values (VTL and VTH) with regards to REF.



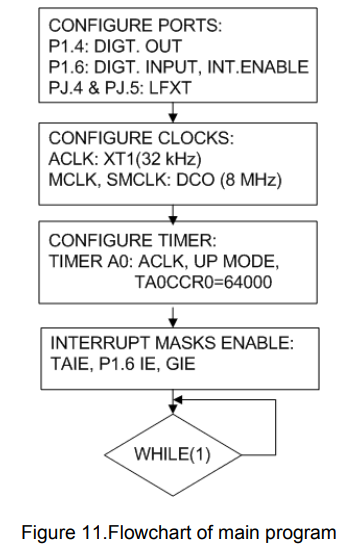
https://www.analog.com/en/analog-dialogue/articles/curing-comparator-instability-with-hysteresis.html

V\_TL(V\_REF) = ((10M + 430k) \* V\_REF – (10M \* 0V)) / 430k

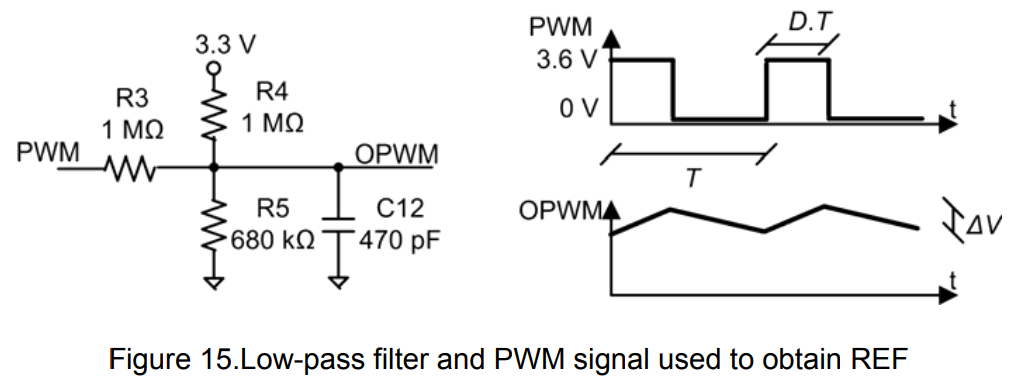
V\_TL(V\_REF) = ((10M + 430k) \* V\_REF – (10M \* 3.6V)) / 430k



4.3 Program the subroutines to control SHDN signal from the comparator output COUT and observe VIN and SHDN in the oscilloscope. The program comprises a main program and two interrupt services (Timer A and P1.6). The main program configures general digital ports, clocks, timer A and interrupts masks as is shown in Fig.11. Do not configure non used ports.



5. REFERENCE VOLTAGE GENERATION The objective of this design stage is software control of photovoltaic panel’s bias voltage (REF). This analogue signal is obtained from the average value of a PWM signal (OPWM). The low-pass filter used in the project board is shown in Fig.15. Figure 15.Low-pass filter and PWM signal used to obtain REF



5.1 Use the circuit of Fig.15 to calculate the value of OPWM versus the value of PWM’s duty cycle (D).

Theoretical:

Measure

0% 990mV U\_ref, 0V PWM

100% 1,83V U\_ref , 3.6V PWM

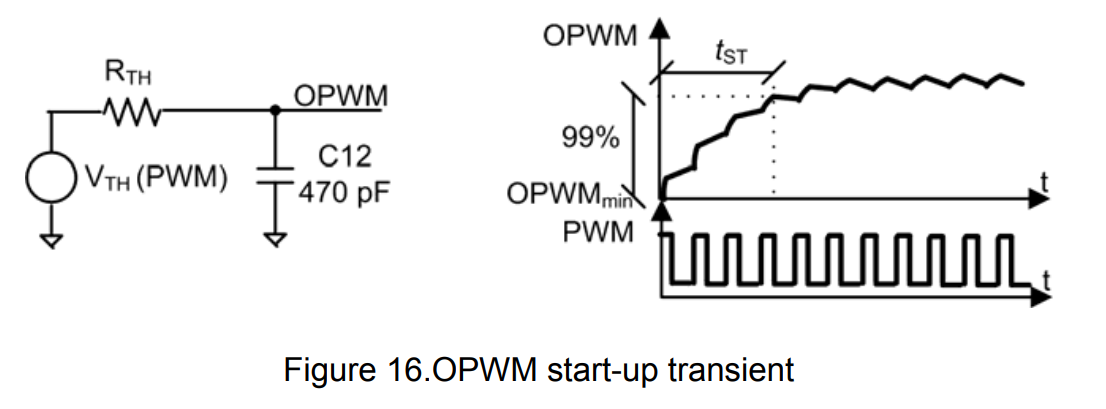
5.2 Considering that T=TBCCR0/fDCO (fDCO=8 MHz and TBCCR0=25), calculate the maximum voltage ripple of OPWM in full range of D. The voltage ripple is so small that the slopes of OPWM can be considered constants during charge and discharge states (linear OPWM shapes).

T = 25/8e6 = 0,000003125s = 3,125 µs

is equal to 320kHz

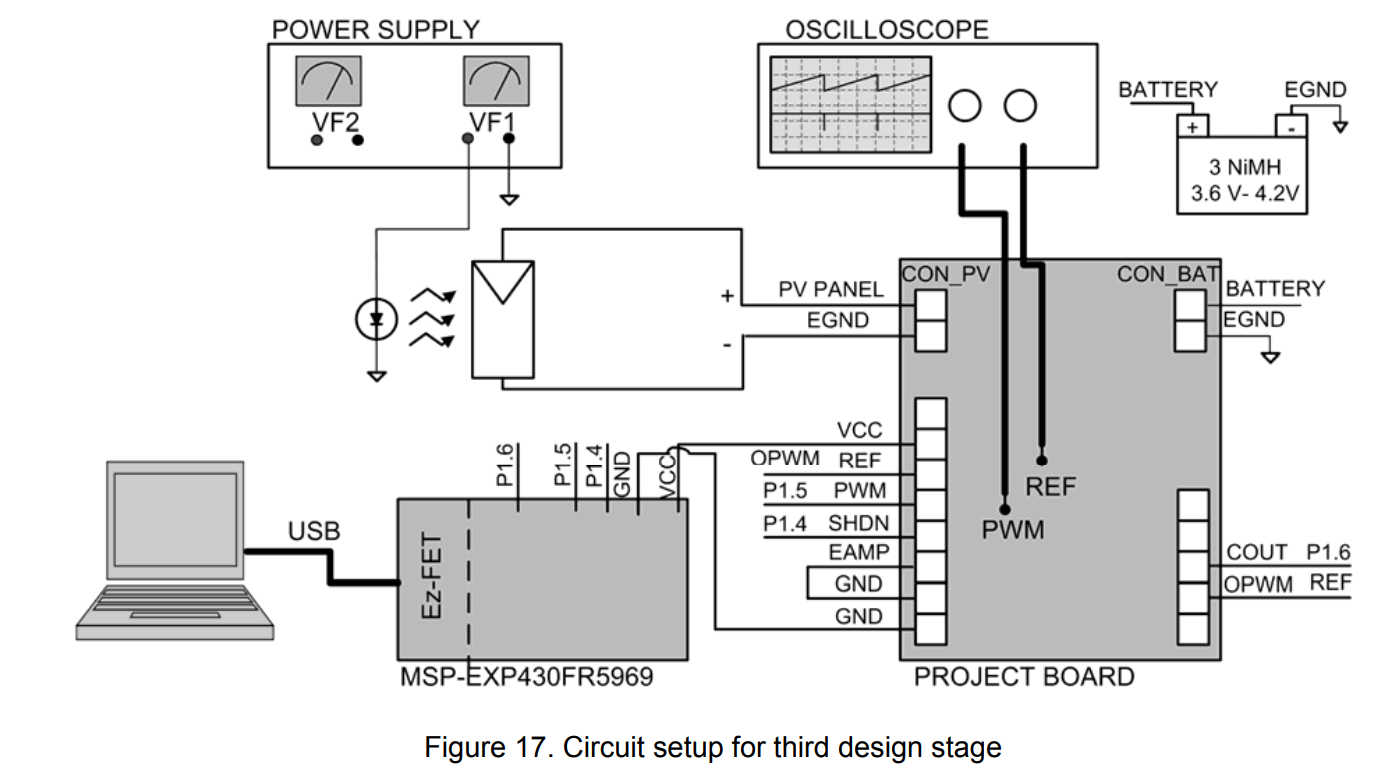
U\_C = U\_0 \* e^(-(t/R\*C)) = 3,6

5.3 The analogue signal generator must be fast enough disabled or enabled to save energy (dynamic power management). Calculate the value of RTH and VTH of the Thevening equivalent circuit shown in Fig.16 and deduce the time length (tST) needed to reach the 99% of final value.



U\_C = U\_0 \* 1 - e^(-(t/R\*C)) = t (99%) = 1,6ms

5.4 Connect the boards and instruments as shown in Fig.17. The potentiometer is substituted by the analogue signal OPWM. The PWM signal is obtained from P1.5 and OPWM is connected to REF. If it is possible, use a 10:1 oscilloscope’s probe to measure OPWM (=REF). Otherwise, the use of a 1:1 probe would modify the waveform of OPWM because the probe’s impedance (1 MΩ) has the same order of magnitude than RTH.



5.5 Modify the main program as shown in Fig.18. The port P1.5 is set as CCR2 OUT2 (output of PWM signal) and Timer B must be driven by SMCLK (DCO) in Up Mode. Take into accounts that P1 Page 11 grey blocks in the flow charts already exist in previous versions but need to be modified. Black blocks are exactly the same as in previous version and hence no changes are needed.

Figure 18. Flowchart of main program

5.6 Fig.19 sums up the architecture and operation of Timer B and PWM generator. SMCLK is selected as clock source. PWM signal (P1.5) is obtained by comparing Timer counter (TB0R) with TBCCR2. The timer works in Up Mode and thus TB0R is reset each time reaches TBCCR0. Use the expression OPWM(D) deduced in 5.1 to deduce the relationship OPWM(TBCCR2).

OPWM(%duty) = 1 + 0.9\*duty

OPWM(TBCCR2) = 1 + 0.9\*(TBCCR2/25)

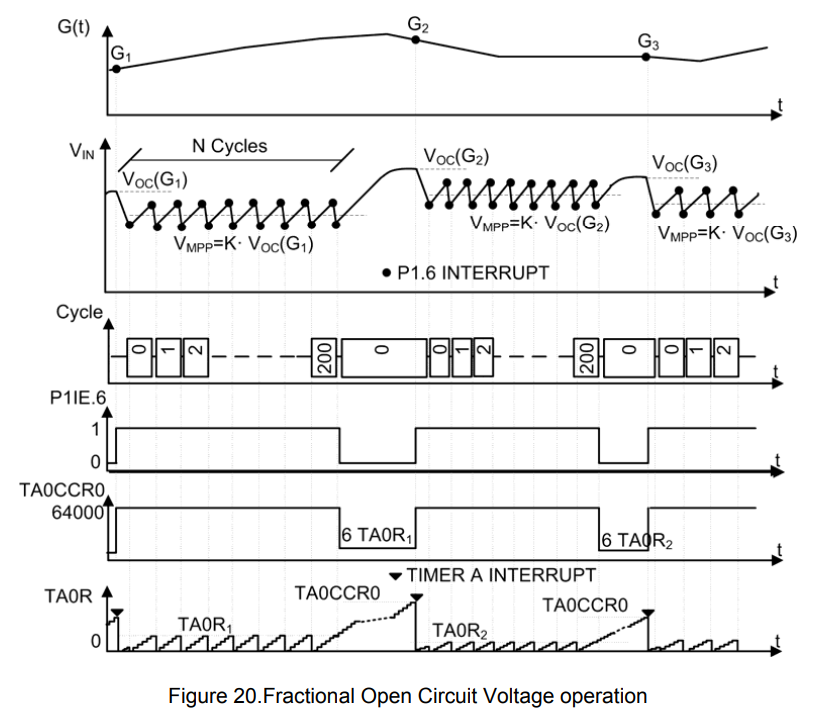
TBCCR2(OPWM) = ( OPWM - 1 ) / ( 0.9 / 25 )

Figure 19.PWM signal generation P1 Page 12

5.7 Test the system operation using the oscilloscope for different values of TBCCR2. Observe VIN in the oscilloscope. ¿Does the switching limits correspond to the theoretical expression obtained in 5.6?

They are a bit lower

6. FRACTIONAL OPEN CIRCUIT VOLTAGE CONTROL LOOP In this design stage μController will set periodically the value of TBCCR2 to bias the PV panel at MPP. TBCCR2 will depend on the open circuit (VOC), periodically sampled, according to relationship VMPP = KVOC found in section 3. The system operation is summed up in Fig.20. A global integer variable (Cycle) is used to account the charge cycles. The sampling stage of VOC starts when Cycle reaches 200. P1IE.6 is disabled to avoid new discharges during 6 charge periods (TA0CCR0 = 6 TA0R1) and VIN rises up to VOC. Analogue Signal Converter (ADC) acquires a new value of VOC each time TA0R reaches TA0CCR0 (Timer interrupt). The resulting data from ADC (ADC12MEMx) is used to calculate the new value of TBCCR2.



6.1 Taking into account that ADC uses 12 bit resolution, VR+ = AVCC = 3.6 V and VR- = AVSS = 0 V, deduce the relationship between TBCCR2 (PWM input register) and ADC12MEM10 (ADC(VOC) output register) to achieve VMPP = KVOC obtained in section 3. Use the expression OPWM(TBCCR2) deduced in 5.6.

***12 Bit Resolution***

***TBCCR2 = 0 … 26***

6. FRACTIONAL OPEN CIRCUIT VOLTAGE CONTROL LOOP

In this design stage μController will set periodically the value of TBCCR2 to bias the PV panel at MPP.

TBCCR2 will depend on the open circuit (VOC), periodically sampled, according to relationship VMPP = KVOC found in section 3.

The system operation is summed up in Fig.20.

A global integer variable (Cycle) is used to account the charge cycles.

The sampling stage of VOC starts when Cycle reaches 200.

P1IE.6 is disabled to avoid new discharges during 6 charge periods (TA0CCR0 = 6 TA0R1) and VIN rises up to VOC.

Analogue Signal Converter (ADC) acquires a new value of VOC each time TA0R reaches TA0CCR0 (Timer interrupt).

The resulting data from ADC (ADC12MEMx) is used to calculate the new value of TBCCR2.

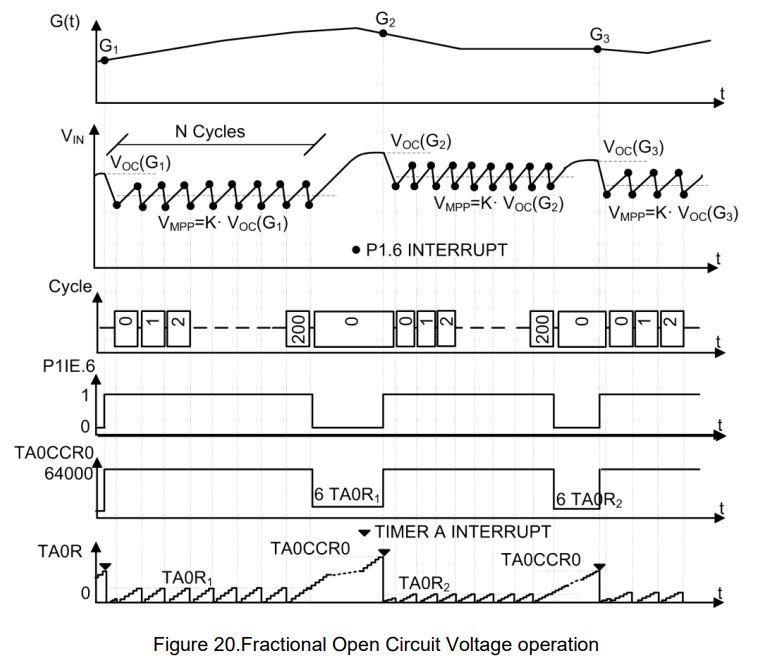
// SETUP ADC PIN FUNCTIONS TO P2.4 A7 and P4.2 A10

P2SEL0 |= BIT4;

P2SEL1 |= BIT4;

P4SEL0 |= BIT2;

P4SEL1 &= ~BIT2;



6.1 Taking into account that ADC uses 12 bit resolution, VR+ = AVCC = 3.6 V and VR- = AVSS = 0 V, deduce the relationship between TBCCR2 (PWM input register) and ADC12MEM10 (ADC(VOC) output register) to achieve VMPP = KVOC obtained in section 3. Use the expression OPWM(TBCCR2) deduced in 5.6.