

Design and Development of a Maximum Power Point Tracking (MPPT) charge controller for Photo-Voltaic (PV) power generation system

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Abstract : This paper portrays how to execute MPPT utilizing the most mainstream exchanging power supply topology. There are numerous distributed takes a shot at this subject, however just a little bit of them demonstrate to really actualize the calculations in equipment, and additionally state normal issues and entanglements. In our work to keep the plan straightforward we have utilized Arduino Nano. It has highlights like: LCD show, Led Indication and it is outfitted with different securities to shield the hardware from anomalous condition. This plan is reasonable for a 50W sun powered board to charge a usually utilized 12V lead corrosive battery. As the maximum power point (MPP) of photovoltaic (PV) power age frameworks changes with changing environmental conditions (e.g. sun based radiation and temperature), an imperative thought in the plan of effective PV frameworks is to track the MPP accurately. We have actualized the most well-known MPPT calculation named Perturb and Observe (PO) to control the yield of a synchronous buck-converter.

IndexTerms - Photovoltaic systems, MPPT techniques, Perturb and Observe, Buck converter, Arduino.

I. INTRODUCTION

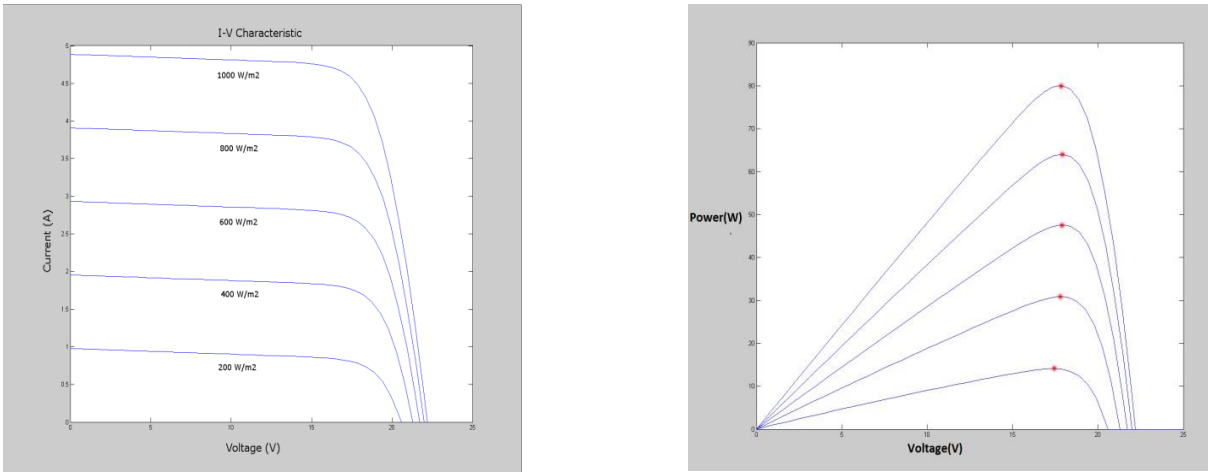
Utilizing a sun powered board or a variety of boards without a controller that can perform Maximum Power Point Tracking (MPPT) will regularly bring about squandered power, which at last outcomes in the need to introduce more boards for a similar power necessity. For littler/less expensive gadgets that have the battery associated specifically to the board, this will likewise bring about untimely battery disappointment or limit misfortune, because of the absence of an appropriate end-of-charge technique and higher voltage. Temporarily, not utilizing a MPPT controller will bring about a higher establishment cost and, in time, the expenses will raise because of possible hardware disappointment. Indeed, even with a legitimate charge controller, the possibility of paying 30-half more in advance for extra sun oriented boards makes the MPPT controller exceptionally alluring [1]. The buck converter is utilized since it has a straight voltage exchange work while working in Continuous Conduction Mode (CCM). This rearranges things a ton, and the MPPT controller can be executed by working specifically on the converter obligation cycle. Alternate topologies have a nonlinear voltage exchange work, and working straightforwardly on the obligation cycle will yield unusual outcomes, particularly at high obligation cycles. For this situation, the calculation alters the sun oriented board working voltage by utilizing a corresponding vital (PI) control circle, which guides the voltage to the coveted esteem [2-9]. In the consequent piece of this paper, the segment 2 shows the essentials of MPPT. In area 3 the PO calculation is clarified to sum things up. The Buck converter is talked about in segment 4. The aggregate equipment plan strategy is outlined in area 5 and 6. The yield comes about are displayed in area 7. At last finishing up comments are incorporated into area 8.

II. MAXIMUM POWER POINT TRACKING

Maximum power point following (MPPT) is a procedure utilized with wind turbines and photovoltaic (PV) heavenly bodies to expand power yield. PV heavenly bodies exist in a few unique designs. The most essential rendition sends power from authority boards specifically to the DC-AC sun powered inverter, and from that point straightforwardly to the electrical framework. A second form, called a half breed inverter, may part the power at the inverter, where a level of the power goes to the framework and the rest of to a battery bank. The third form isn't associated at all to the framework yet utilizes a devoted PV inverter that highlights the MPPT. In this arrangement,

power streams specifically to a battery bank. A minor departure from these arrangements is that rather than just a single inverter, smaller scale inverters are conveyed, one for each PV board. This professedly expands PV sunlight based effectiveness by up to 20%. New MPPT prepared claim to fame inverters currently exist that serve three capacities: lattice interfacing wind power and in addition PV, and expanding power for battery charging. [10]

This paper is about the utilization of MPPT concerns itself just with PV sun powered. Sun powered cells have a mind boggling connection amongst temperature and aggregate opposition that creates a non-direct yield effectiveness which can be examined in light of the I-V bend as appeared in figure 1. It is the reason for the MPPT framework to test the yield of the PV cells and apply the correct opposition (stack) to get maximum power for any given natural conditions. MPP (Maximum power point) is the result of the MPP voltage (V_{mpp}) and MPP current (I_{mpp}) [12].



(Figure 1.(a) IV characteristics of PV panel for different irradiance level .
(b) PV characteristics corresponding to IV characteristics in (a).

Red dot shows the Maximum power point (MPP).

The creator [10, 11] looks at and assesses the level of power extraction with MPPT and without MPPT.

It plainly demonstrates that when we utilize MPPT with the PV framework, the power extraction proficiency is increment to 97%. The investigation of building up a PV charging framework for li-particle batteries by coordinating MPPT and charging control for the battery is evaluated. The general square chart of PV board with dc-dc converter and MPPT is appeared in figure2.

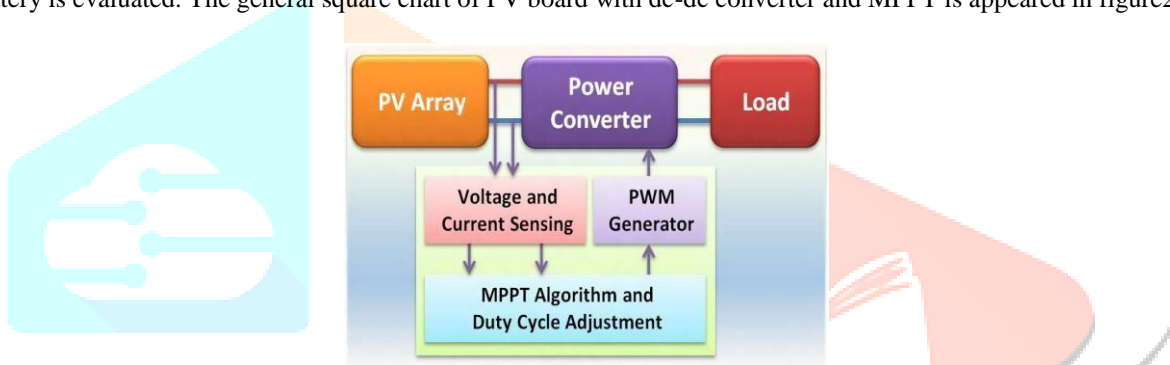


Figure 2. Block diagram of a MPPT controller.

III. PERTURB & OBSERVE ALGORITHM

The perturb and observe (P&O) calculation, otherwise called the "slope climbing" technique, is exceptionally mainstream and the most normally utilized as a part of training on account of its straightforwardness in calculation and the simplicity of usage. The most fundamental type of the P&O calculation works as takes after. Figure 17 demonstrates a PV module's yield power bend as a component of voltage (P-V bend), at the consistent irradiance and the steady module temperature, accepting the PV module is working at a point which is far from the MPP. In this calculation the working voltage of the PV module is perturbed by a little addition, and the subsequent difference in power, P, is observed. On the off chance that the P is sure, at that point it is assumed that it has drawn the working point nearer to the MPP. In this way, promote voltage perturbations a similar way should push the working point toward the MPP. On the off chance that the P is negative, the working point has moved far from the MPP, and the bearing of perturbation ought to be turned around to move back toward the MPP [13]. Figure 3 demonstrates the flowchart of this calculation..

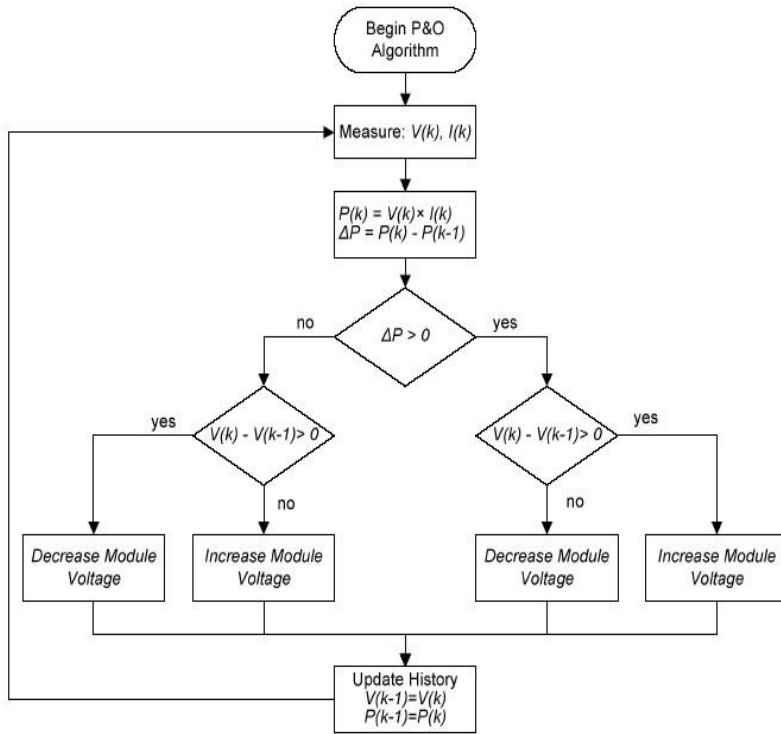


Figure 3. Flow Chart of PO algorithm used in our MPPT charge controller.

IV.SWITCHED MODE DC-DC CONVERTERS

The core of MPPT equipment is a switch-mode DC-DC converter. It is generally utilized as a part of DC power supplies and DC engine drives to convert unregulated DC contribution to a controlled DC yield at a coveted voltage level. MPPT utilizes a similar converter for an alternate reason: directing the information voltage at the PV MPP and giving burden coordinating to the maximum power exchange. As expressed above, in our outline we have utilized the buck converter. The guideline of the buck converter is exhibited beneath.

4.1 The Buck Converter

A buck converter is a stage down DC to DC converter. it is an exchanged mode power supply that utilizations two switches (a transistor and a diode), an inductor and a capacitor.

4.1.1 Theory of operation

The activity of the buck converter is genuinely basic, with an inductor and two switches (generally a transistor and a diode) that control the inductor. It substitutes between associating the inductor to source voltage to store vitality in the inductor and releasing the inductor into the heap.

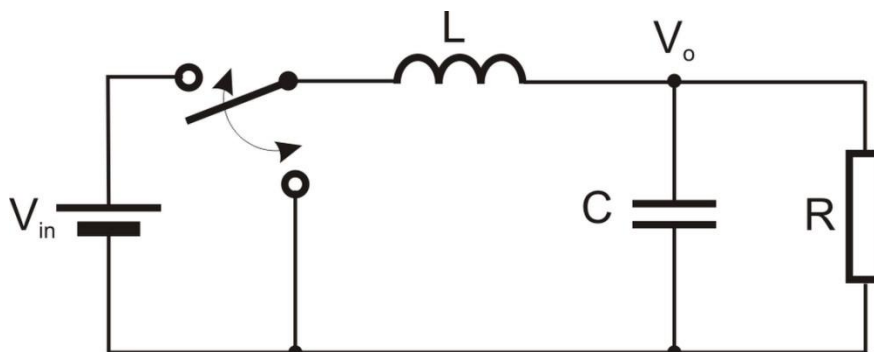


Figure 4.BuckConverter

For the motivations behind investigation it is helpful to think about an admired buck converter. In the romanticized converter every one of the segments are thought to be great. Particularly the switch and the diode have zero voltage drop when on and zero current stream when off and the inductor has zero arrangement opposition. Promote it is accepted that the information and yield voltages don't change through the span of a cycle (this would infer the yield capacitance being boundlessly substantial). A buck converter works in continuous mode if the current through the inductor (IL) never tumbles to zero amid the compensation cycle. In this mode, the working rule is depicted underneath:

At the point when the switch presented above is shut (On-state, best of figure 2), the voltage over the inductor is $V_i - V_o$. The current through the inductor rises directly. As the diode is switch one-sided by the voltage source V , no present moves through it; At the point when the switch is opened (off state, base of figure 2), the diode is forward one-sided. The voltage over the inductor is $-V_o$ (disregarding diode drop). Current I_L diminishes.

The vitality put away in inductor L is

$$E = \frac{1}{2} L \times I_L^2 \tag{1}$$

Along these lines, it can be seen that the vitality put away in L increments amid On-time (as I_L increments) and then reductions amid the Off-state. L is utilized to exchange vitality from the contribution to the yield of the converter.

The rate of progress of I_L can be ascertained from:

$$V_L = L \frac{dI_L}{dt} \tag{2}$$

With V_L equal to $V_i - V_o$ during the On-state and to $-V_o$ during the Off-state. Therefore, the increase in current during the On-state is given by:

$$\Delta I_{L_{on}} = \int_0^{t_{on}} \frac{V_L}{L} dt = \frac{(V_i - V_o)}{L} t_{on} \tag{3}$$

Identically, the decrease in current during the Off-state is given by:

$$\Delta I_{L_{off}} = \int_{t_{on}}^{T=t_{on}+t_{off}} \frac{V_L}{L} dt = -\frac{V_o}{L} t_{off} \tag{4}$$

On the off chance that we expect that the converter works in unflinching state, the vitality put away in every part toward the finish of a recompense cycle T is equivalent to that toward the start of the cycle. That implies that the present I_L is the same at $t = 0$ and at $t = T$ (see figure 4).

So we can compose from the above conditions:

$$\frac{(V_i - V_o)}{L} t_{on} - \frac{V_o}{L} t_{off} = 0 \tag{5}$$

It is worth noting that the above integrations can be done graphically: In figure 4, $\Delta I_{L_{on}}$ is proportional to the area of the yellow surface, and $\Delta I_{L_{off}}$ to the area of the orange surface, as these surfaces are defined by the inductor voltage (red) curve. As these surfaces are simple rectangles, their areas can be found easily:

for the yellow rectangle $(V_i - V_o)t_{on}$ and for the orange one $-V_o t_{off}$. For steady state operation, these areas must be equal. As can be seen on figure 4, $t_{on} = DT$ and $t_{off} = (1-D)T$. D is a scalar called the duty cycle with a value between 0 and 1. This yield:

$$\begin{aligned} (V_i - V_o)DT - V_o(1 - D)T &= 0 \\ \Rightarrow V_o - DV_i &= 0 \\ \Rightarrow D &= \frac{V_o}{V_i} \end{aligned}$$

From this equation, it can be seen that the output voltage of the converter varies linearly with the duty cycle for a given input voltage. As the duty cycle D is equal to the ratio between t_{on} and the period T , it cannot be more than 1. Therefore, $V_o \leq V_i$. This is why this converter is referred to as step-down converter. So, for example, stepping 12 V down to 3 V (output voltage equal to a fourth of the input voltage) would require a duty cycle of 25%, in our theoretically ideal circuit

V. SYSTEM OVERVIEW.

The overall system diagram can be viewed as in figure 5. The Required specifications are given in table 1.

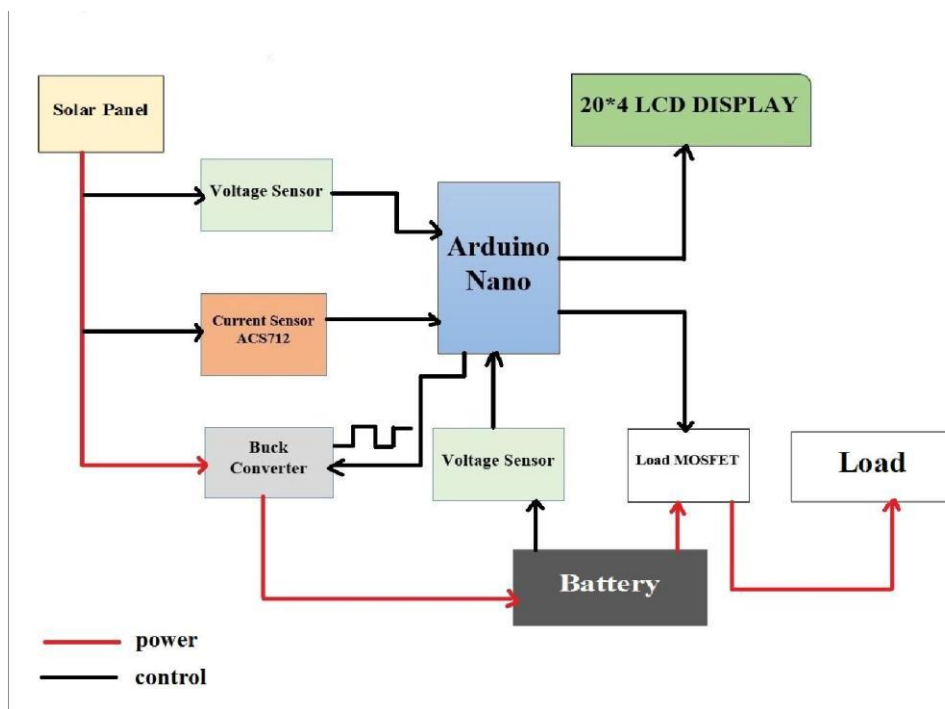


Figure 5. System block diagram.

Table 1. Features of the MPPRT controller

Specification of the prototype of solar charge controller	Electrical Specification Of Buck Converter
<ol style="list-style-type: none"> 1. Based on Perturb and observe MPPT algorithm 2. LED indication for the state of charge 3. 20x4 character LCD display for displaying voltages, current, power etc. 4. Overvoltage / Lightning protection. 5. Reverse power flow protection. 6. Short Circuit and 7. Over load protection 	<ol style="list-style-type: none"> 1. Output Voltage = 12 V 2. Max. Output Current = 5A. 3. Output Power = 50 W. 4. Input = 12-25V

VI. IMPLEMENTATION STAGE

In the usage organize most vital assignment was to get the segment as per the determination of the apparatus. There are 2 primary sub organizes likewise: one is the equipment usage and the other is execution of the product. Every one of the parts with appropriate esteem are appeared in the schematic beneath; the product is likewise executed right off the bat in the recreation as we find in figure 6.

□ The information power connector to the sun oriented boards is the screw terminal JP1 and JP2 is the yield screw terminal connector to the battery. The third connector JP3 is association for the heap.

□ F1 and F2 are the 5A wellbeing wires

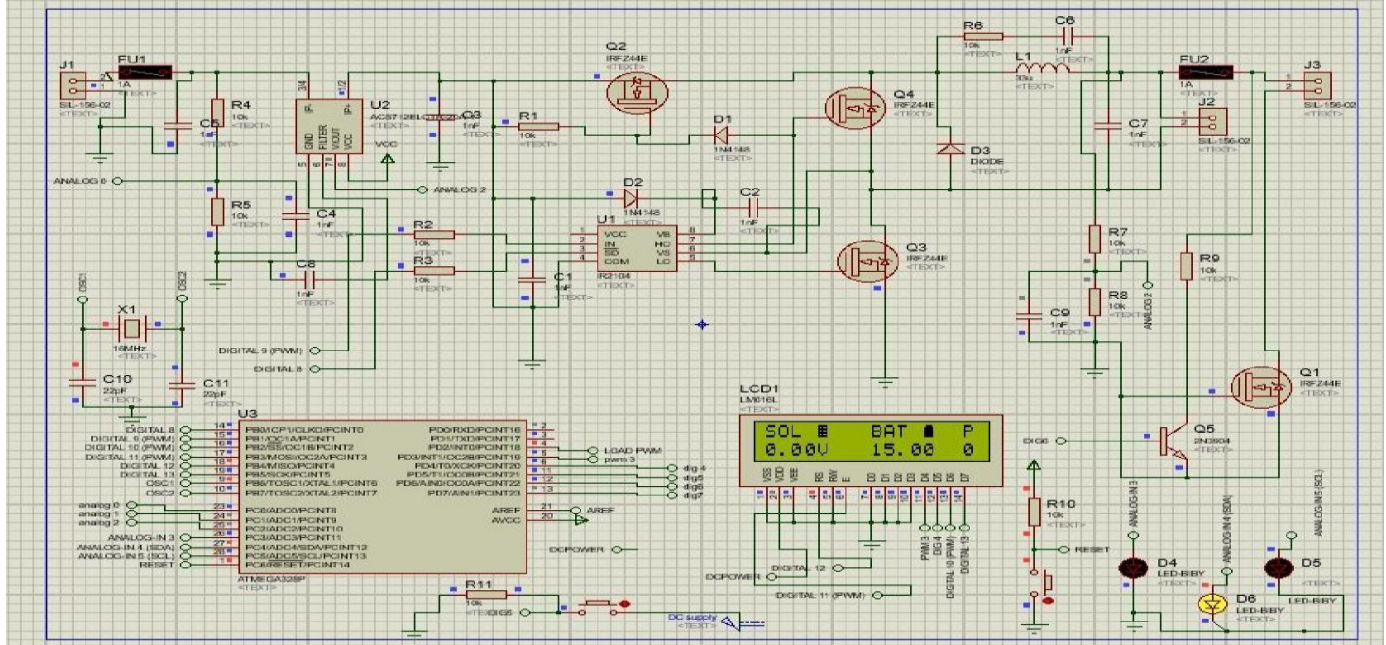


Figure 6. Simulation of the system

- The buck converter is comprised of the synchronous MOSFET switches Q2 and Q3 and the vitality stockpiling gadgets inductor L1 and capacitors C1 and C2. The inductor smooths the exchanging current and alongside C2 which smooths the yield voltage.
 - Capacitor C8 and R6 are a snubber system, used to eliminate the ringing of the inductor voltage created by the exchanging current in the inductor.
 - The third MOSFET Q1 is added to enable the framework to hinder the battery power from streaming once more into the sunlight based boards during the evening. As all diodes have a voltage drop a MOSFET is substantially more efficient.Q1 turns on when Q2 is on from voltage through D1. R1 channels the voltage off the door of Q1 so it kills when Q2 kills.
 - The diode D3 (HER 507) is a ultra-quick diode that will begin leading current before Q3 turns on. It should make the converter more productive.
 - The IC IR2104 is a half scaffold MOSFET entryway driver. It drives the high and the low side MOSFETs utilizing the PWM motion from the arduino (Pin - D9) .The IR2104 can likewise be closed down with the control flag (low on stick - D8) from the Arduino on stick 3.
 - D2 and C7 are a piece of the bootstrap circuit that creates the high side entryway drive voltage for Q1 and Q2.
- The product monitors the PWM obligation cycle and never permits 100% or dependably on. It tops the PWM obligation cycle at 99.9% to keep the charge pump working.
- There are two voltage divider circuits (R 1 , R 2 and R3,R4) to quantify the sun based board and battery voltages. The yield from the dividers are encourages the voltage flag to Analog stick 0 and Analog stick 2 .
 - The clay capacitors C3 and C4 are utilized to expel high recurrence spikes.
 - The MOSFET Q4 is utilized to control the heap. The driver for this MOSFET is comprises of a transistor and resistors R9 , R10.
 - The diode D4 and D5 are TVS diodes utilized for over voltage assurance from sun based board and load side.
 - The current sensor ACS712 sense the current from the sun powered board and feeds to the Arduino simple stick 1.
 - The 3 LEDs are associated with the advanced pins of the microcontroller and fill in as a yield interface to show the charging state.
 - Reset switch is useful if the code stalls out.
 - The backdrop illumination change is to control the backdrop illumination of LCD show.

VII. Equipment TESTING STAGE

In this progression particularly the info and yield of the buck converter is tried.

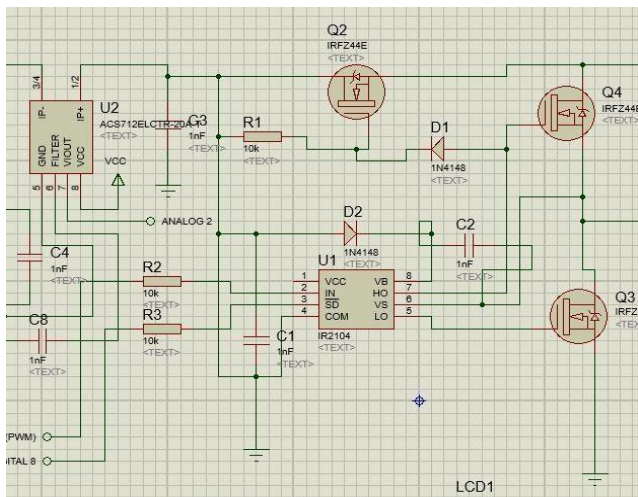


figure: Testing Schematic

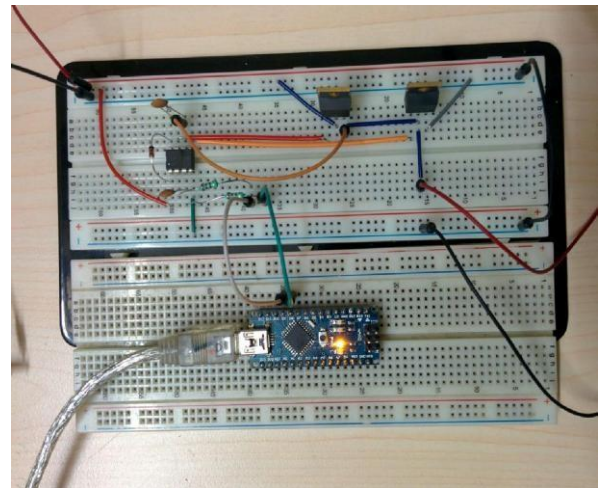


Figure 7. Test schematic (Left) and Hardware prototype of the (Right) system.

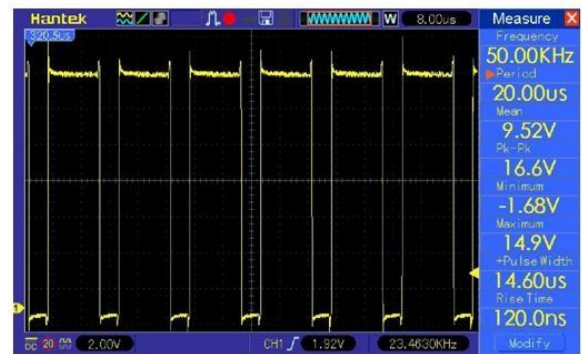
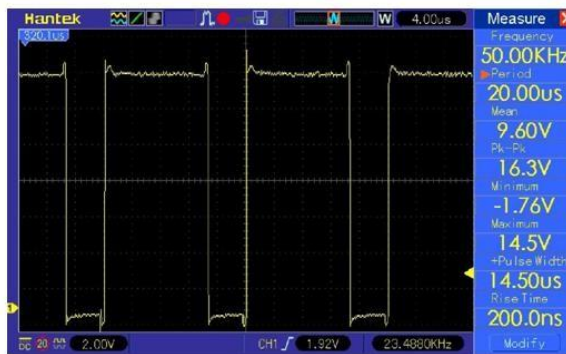


Figure 8. PWM output from the Arduino.

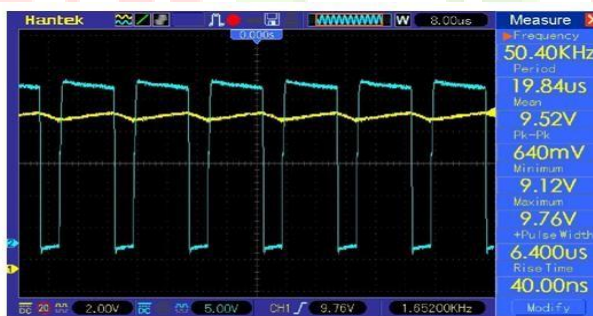


Figure 9. Output of the Buck converter (Left). The complete prototype using Arduino.(Right)

VIII. CONCLUSION

The Maximum Power Tracker utilizes an iterative way to deal with discovering this continually evolving MPP. This iterative technique is called slope climbing calculation. To accomplish MPPT, the controller alters the voltage by a little sum from the sun based board and measures power, if the power increments, advance alterations toward the path are attempted until power never again increments. The voltage to the sun based board is expanded at first, if the yield power increment, the voltage is consistently expanded until the point when the yield power begins diminishing. Once the yield power begins diminishing, the voltage to the sun based board diminished until the point when maximum power is come to. This process is proceeded until the point when the MPPT is accomplished. This outcome is a wavering of the yield power around the MPP.

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