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Application Note

Solar Power Inverters

Document No. U20193EU1V0AN00

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Revision History

Date	Revision	Section	Description
01/08/2010	—	—	First release

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1. Introduction

This application note provides a guide to designing solar power inverters with NEC Electronics' 8-bit, 16-bit and 32-bit microcontrollers (MCUs). This document includes:

- Overview of solar power solutions
- The solar power inverter
- MCU selections for solar power inverters

Solar power is truly a free source of energy which requires only the means of capturing, storing and smart distribution without the pollution associated with conventional sources such as burning fossil fuels, or the potential hazards of nuclear power. It is estimated that up to 30% of the conventional energy produced in the world is lost during power transmission over long distance, power conversion and oversupply. The use of locally distributed systems such as solar or wind can overcome most of these losses. It is estimated that the energy delivered to the earth by the sun every day can power our homes and businesses for almost 30 years. Although the energy is free, the technology to capture it and make it available for everyone comes at a cost that is becoming more and more competitive. Funded by private or public money, small start-ups and large energy providers and distributors work effortlessly to develop new materials and more efficient ways to bring down the cost and make it available to a larger customer base. Scalability from small to big, from simple to complex makes solar power one of the most attractive sources of alternative energy. Not only large energy companies but also home owners can benefit from this fast growing industry.

1.1 Definition of Terms

- **Solar power**
  A form of energy harvested from the sun to produce electrical energy.

- **Solar power plant**
  A facility that produces energy from solar power.

- **Photovoltaic cells**
  A cell of light sensitive material that produces a voltage when exposed to sun light

- **Solar panel**
  An array of photovoltaic cells connected in series and parallel to increase the voltage and current output

- **Power conditioner**
  A power circuit connected to the output of solar cells to average the voltage fluctuations due to the fluctuations of solar light intensity and temperature

- **DC/DC buck converter**
  Converts a DC voltage on the input to a lower value on the output

- **DC/DC boost converter**
  Converts a DC voltage on the input to a higher value on the output

- **Battery charger**
  A circuit used to store the DC voltage produced by the solar cells and insure uninterrupted source of energy when the sun activity is low.

- **Maximum Power Point Tracking**
  A circuit used to track the solar panel voltage and current and determine the maximum power the panel can deliver under different illumination and temperature conditions

- **Power inverter**
  A power circuit used to invert the DC voltage produce by the solar cells into AC voltage that can be used by regular appliances.

2. Overview of solar power solutions

Solar power can be harvested in two ways: Produce electrical power directly from the sun light using photovoltaic solar panels as DC or AC source voltage, or use the heat produced by the sun to heat up steam to drive a turbine to produce electricity. The subject of this application note is focused on the first of the two which we will call for convenience the photovoltaic method.

One of the most important aspects of energy production from the sun is the availability of steady sun light throughout the day and year. Location of the plant is also very important as not all areas of the globe have enough sun light to justify the expense. Places in the USA like: California, Nevada and Arizona where the sun shines between 250 to 300 days a year, are ideal sites to set-up solar energy production. Even though there is plenty of sun light in these areas, to maintain a steady flow of electrical energy is a challenge. Although on darker days there is still some sun light, the electrical output is quite diminished. At night obviously there is no sun light at all. The first problem can be easily dealt with by storing the energy produced when the sun shines to compensate for darker days. For the second problem there is no solution. But since the peak demands are during the day to maximize energy production when sun light is available is crucial to justify the investment. For the above reasons obviously solar power can't be a standalone source of energy, it has to be combined with other forms of production. On the other hand since it is considered free and the cleanest off all, the more we use it the less we need other forms that are polluting the environment and are becoming less and less available as well as more expensive to provide. Solar energy production is clearly the way of the future. We just need to make it cheaper and available to a larger consumer base.

3. The solar power plant

Unlike other electrical energy production methods where the facilities are very large industrial type, the energy from solar power can be produced on a very small to medium, to very large industrial scale. To distribute the energy to the consumer, with traditional methods a large infrastructure and strict commercial and safety regulations are needed. Although when produced on industrial scale, solar power is subject to the same rules, small scale power plants that produced locally are very flexible in terms of capacity voltage and application. The smallest and inexpensive ones can have very limited applications such as toys, landscape lighting etc. Still small but with better quality and reliability can be seen on roadside emergency telephones or cell phone towers. The small scale but large capacity that make a big impact on the industry, are the residential type that homeowners can purchase and often install themselves on the roofs of their houses. These are the fastest growing and becoming less expensive every day. The government and the utility companies are encouraging the consumers to purchase them by offering incentives such as tax rebates and financing support. Some of these plants can produce more energy than the consumer needs. Many of them are equipped with special circuitry to allow feeding the excess energy to the power grid. This enables individual small scale power producers to sell back the energy produced to the utility companies. Just imagine what the future will look like when almost every residence can potentially be a power producer for the entire grid and make money on it.

3.1 Solar power production – the nuts and bolts

A typical solar power plant block diagram is shown in Figure1. The solar panel produces DC voltage when struck by light. The DC voltage is fed through a power conditioner to a DC to AC inverter to power the appliances in our homes and businesses. The AC power can be used locally by a residence, a farm or a small business, or it can be fed to the utility power grid to supplement the energy produced from other sources. Grid connected systems can be permanently connected or stand-alone in which case are called hybrid systems. A power conditioner acts as a battery charger regulator to produces a steady DC voltage level, as well as a noise filter. Batteries are optional in grid connected systems but mandatory in stand-alone systems. Batteries store the energy during high solar activity and make it available during the low ones such as at night.

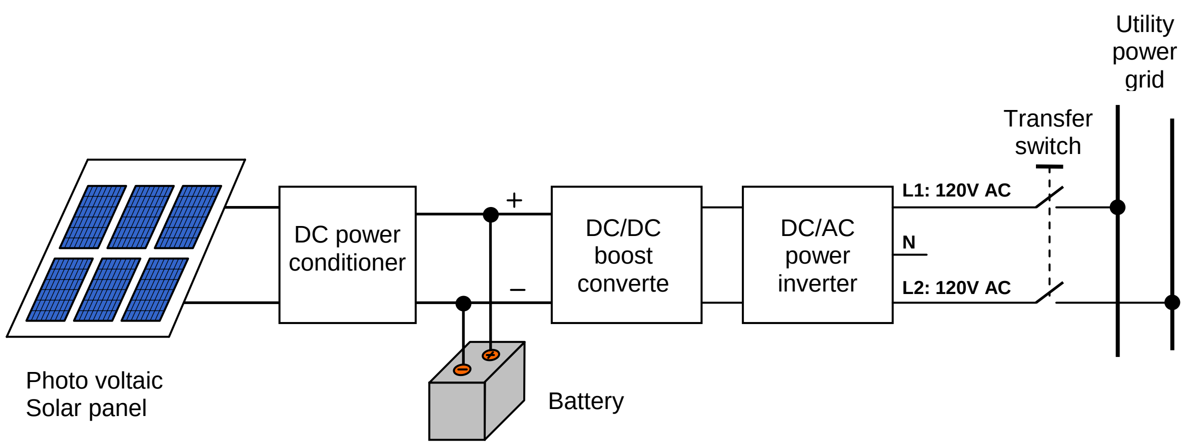

Figure 1 Solar power plant

As part of the power conditioner an electronic circuit prevents over and under charging and maintains optimum battery life. The DC/DC boost converter stage converts the battery voltage which is typically 24V, 48V or 36V, to a higher voltage typically 360V to 380V. The DC/AC power inverter converts the DC voltage to single phase or three phase AC voltage. The inverter output can be connecter to the power grid directly though a transfer switch, to separate the inverter from power grid when the inverter is in stand-alone mode or when a failure occurs. In some countries a separation transformer is mandatory for extra safety.

3.2 DC power conditioner

The DC power conditioner also known as “battery charge controller” is connected between the solar panel output and the battery. It is a key component of a solar power generation system and its main role is to provide a steady and reliable DC voltage to the battery and the DC/AC inverter. The solar panel voltage and current output varies with the sun’s intensity throughout the day and seasons, the orientation and its efficiency. Solar panel arrays can be configuration as series, parallel or mixed and the battery arrays can also be in parallel, series or mixed. Based on this the conditioner can be a DC/DC boost converter or a DC/DC buck converter to either increase or decrease the voltage fed to the batteries. Most residential solar systems use buck topologies. A basic DC/DC buck converter is shown in Figure 2.

A switching device T such as a MOSFET or IGBT is driven by typically a 10 to 100 KHz PWM signal. When transistor T is on the current through the inductor increases and it will charge up capacitor to a voltage proportional to the time T is on. When T is the energy stored in the inductor causes the current through the inductor to continue to flow but it will decrease due to the return path through the diode. The voltage seen by the load will be direct proportional to the ratio between the time the transistor is on and the time it is off. If the transistor gate is controlled with a PWM signal the voltage o the output will be proportional to the duty cycle.

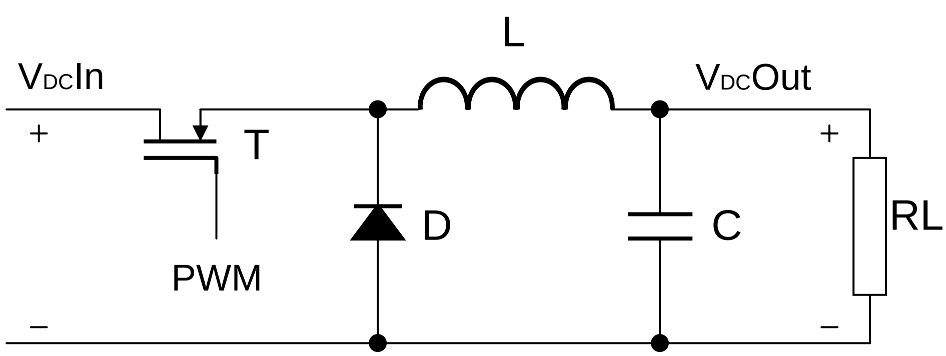

Figure 2 DC/DC buck converter

By monitoring the input voltage the PWM duty can be adjusted to compensate for the variations of VDCIn. This ensures that regardless of solar activity throughout the day and the seasons, a constant voltage level can be maintained.

3.2.1 Maximum Power Point Tracking

Solar panels are rated by the power in Watts they can deliver under load conditions. Standard solar panels can deliver between 16 and 18V at a rated current in ideal conditions of sun shine and orientation. At different times of the day when the sun light is not the strongest the panel output voltage and current will be diminished. The outside temperature also has an effect on the panel output. In the colder winter days the solar cells can put out up to 20% more power which can compensate for the lower solar activity. At any given condition of illumination and temperature and orientation the solar panel has a maximum power output as illustrated in Figure 4.

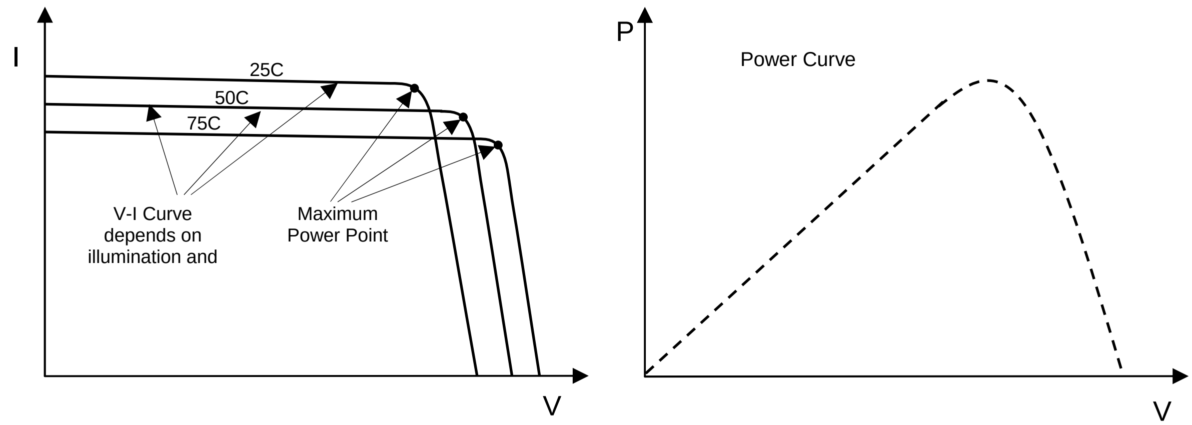

Figure 3 V-I and Power curves

The maximum power a panel can deliver is at the knee of the V-I curve and it corresponds to a maximum power voltage Vmpp and a maximum power current Impp. The corresponding power curve is also shown on the right in Figure 4. If for example Vmpp is 17V and Impp is 3.5A the maximum power that the panel can deliver is 17 x 3.5 = 59.5W. When a 12V battery is directly connected to the solar panel output, the voltage is forced to match the battery voltage which is around 12V. This causes the power transfer from the panel to drop to a value dictated by 12*3.5 = 42 W. Compared with the maximum power point of 59.5 W this is a drop of 30% and it reveals a very inefficient use of the solar panel. The role of a maximum power point tracker (MPPT) is to restore the maximum power transfer to 59.5W using a DC/DC buck converter controlled by a microcontroller and also track the maximum power point changes due to illumination, temperature and orientation. The first part is accomplished by adjusting the DC/DC buck converter switch PWM duty so that the voltage at the panel output is 17V and on the battery input is 12V. If we consider that the converter losses are negligible, the maximum power of 59.5W will be transferred to the battery. Based on a constant power transfer principle, the battery current will be 59.5/12 = 4.95A. This increase I charging current is a direct result of the panel working at the maximum power point on the V-I curve. The second role of the MMPT is to track the maximum power point by measuring the voltage and current on the input and output of the DC/DC buck converter and adjusting the output voltage so that the charging current is maximized. Traditionally MMPT is implemented with analog circuits but microcontrollers offer more flexibility and scalability in terms of controlling both the front end DC/DC buck converter and the battery charging as well as adding features such as temperature monitoring for both: the solar panel and the battery. Ideally in larger systems with many solar panels each panel or panel array has an MMPT controller. In this case a separate microcontroller will be used for MMPT and another one for the inverter function. However for a medium power residential system where the inverter is close to the panels a single-chip solution may be the most cost effective provided that one microcontroller can handle all the tasks. This application note will show an example of how this can be achieved with an NEC Electronics microcontroller.

3.3 DC/DC boost converter

The role of the DC/DC boost converter stage is to increase the battery voltage to a 350V to 380 V for the DC/AC inverter. As shown in Figure 4, a switching device a MOSFET or IGBT is driven by typically a PWM signal of 10KH to 100 KHz. When the transistor is on the current flows through the inductor to the ground. When the transistor is off, the energy stored in the inductor generates a voltage with positive polarity at the anode the diode. The voltage seen on the anode of diode D is the sum of inductor voltage and VDCIn and it charges up capacitor C to a higher voltage than the input VDCIn, making it a boost DC/DC converter. The voltage on the output can be precisely controlled by the duty cycle of the PWM signal. By monitoring the output voltage the PWM duty can be adjusted to maintain a certain value.

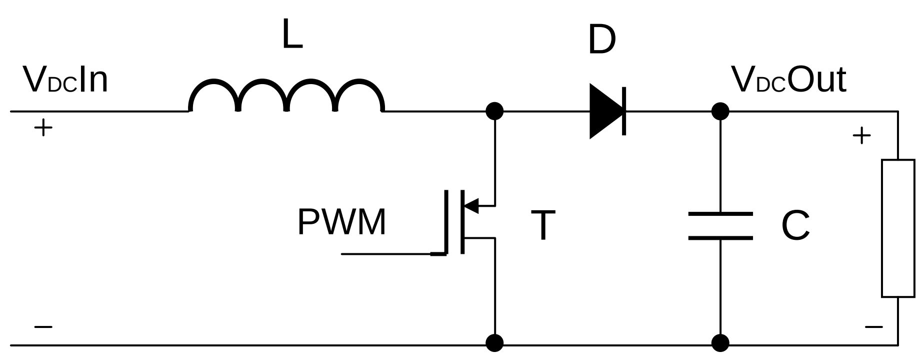

Figure 4 DC/DC boost converter

4. Power inverter

The power inverter stage is by far the most important component of the entire solar power system. A basic inverter configuration contains a number of switching devices such as power MOSFETs or IGBTs connected in a bridge topology. The role of the inverter is to convert the DC voltage generated by the solar cells to an AC voltage that can power ordinary household appliances. Power inverters can be single phase or three-phase, depending on the application. Most residential power systems in the US use single phase tree-wire topologies as shown in Figure 5. The voltage between each line (L1 or L2) to neutral (N) is 120V and between L1 and L2 is 240V. The power inverter contains six switching devices to generate three independent voltage levels or phases. In three-phase systems these voltages are called U, V and W (or R, S and T) and are of the same amplitude and frequency but 120 deg out of phase with each other. In a single phase three-wire system the two of the phases are L1 and L2 and the third phase is used as a neutral. To generate the AC waveforms the bridge transistor gates are controlled by a microcontroller with pulse-width modulated signals. To filter out the high frequency components on the inverter output, low-pass LC networks are used. A detailed description of how PWM methods can generate the AC voltages can be found in following chapter of this application note. Some inverter systems are stand-alone and are used as local power sources for a remote building such as a house or farm etc. This type of systems, require batteries to store energy during the day for the evening and night. Other inverter systems are partially or fully grid connected to be able to supply the excess energy to the utility company. These systems may or may not have batteries. A grid connected single phase three-wire inverter is shown in Figure 5. A transfer switch is always used to connect or separate the inverter from the grid. In some countries an isolation transformer is mandatory to prevent any DC components to get into the utility lines as well as to minimize the negative effects of potential inverter failure. In grid connected systems, special circuitry is necessary to monitor the line voltages and frequency to ensure synchronous operation. A key safety problem occurs when the utility company decides to shot down the power to the lines. The power inverter controller needs to detect the situation and disconnect the inverter from the power grid “islanding” itself.

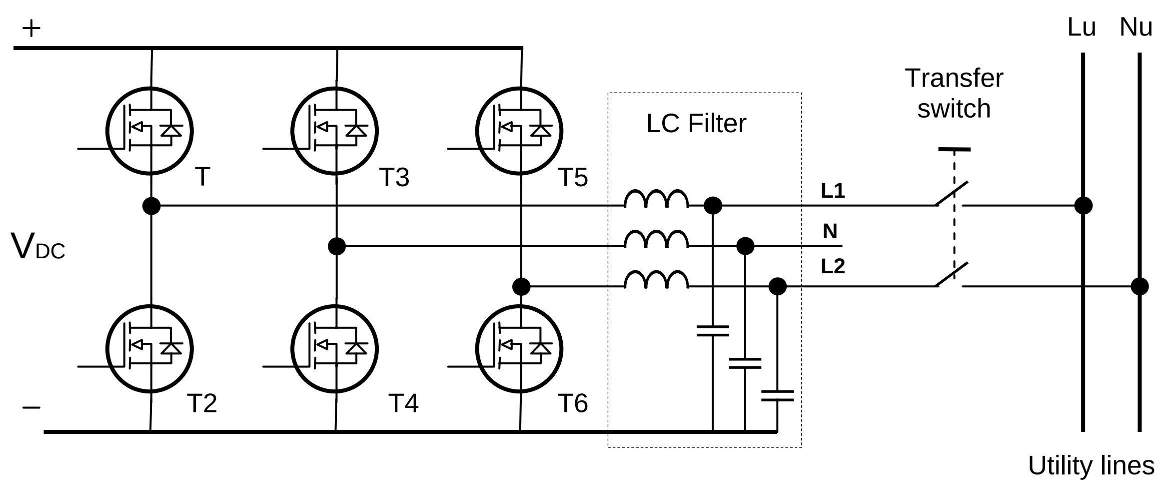

Figure 5 Grid connected single phase three-wire inverter

A three-phase inverter connected through a transformer to the utility grid is shown in Figure 6. The transformer can be a 1:1 separation transformer or a step-up to allow connection to a higher grid voltage.

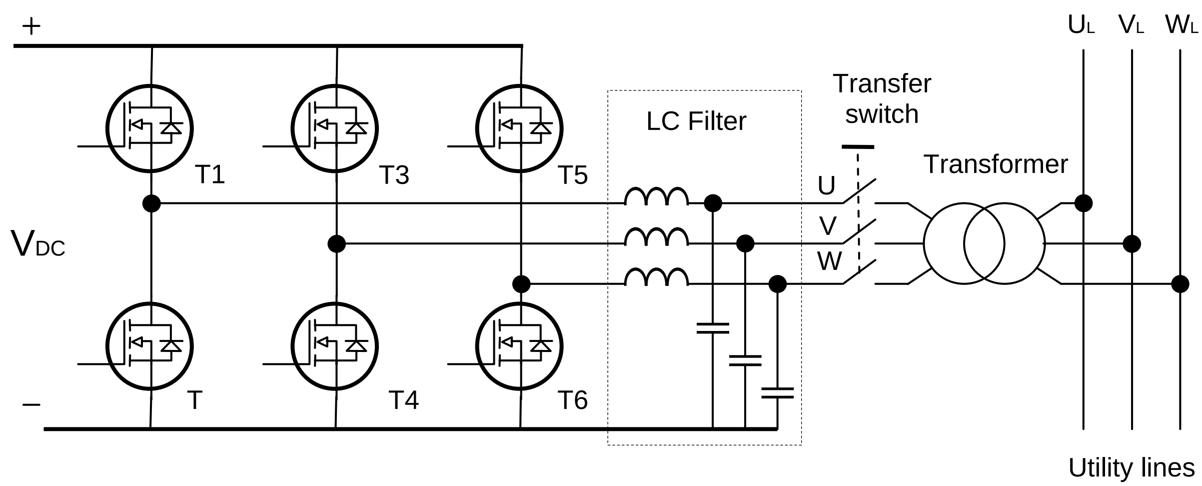

Figure 6 Three-phase inverter grid connected with transformer

4.1 Inverter Operation

With a bridge configuration as shown in Figure 5 and Figure 6, the voltage at the common point of each transistor pair can swing between $+V_{DC}$ and $–V_{DC}$. This voltage swing will have to be sinusoidal over time with a period of 60 Hz and in the case of three phase systems each with 120 Deg phase delay between common points.

In a single phase three wire system as shown in Figure 5, to generate 240V RMS between L1 and L2, VDC needs to be at least 240 *√2 = 338.4 V. If we account for a maximum of 10% voltage margin, the DC bus voltage should be around 372V.

To generate the sinusoidal voltage swings the gates of the bridge transistors are driven with typically 10Khz to 20Khz PWM signals with duty cycles changing sinusoidal over time at the rate of 60Hz. For each transistor pair T1/T2, T3/T4, T5/T6 the top transistor is driven with a unique PWM signal and the bottom with its complement. A dead-time is inserted between the complementary signals to prevent shoot-through to DC ground. To generate sinusoidal PWM signals analog circuitry can be used but a more cost effective way when thinking about the entire system is to synthesize a sine wave digitally using a microcontroller. In the following paragraphs we will look at both methods: the first one as a basic concept, the second one in more detail.

4.1.1 Sinusoidal pulse width modulation

A simple way to generate sinusoidal PWM is to use analog circuit as shown in Figure 7. A high frequency triangular carrier signal of typically 10KHz to 20KHz is intersected with a low frequency sine wave using an analog comparator. The generation of the two input signals requires additional circuitry not shown in this example. The resulting waveform on the comparator output is a PWM signal with a frequency equal to that of the triangular wave and a duty cycle that is modulated by the 60Hz sine wave.

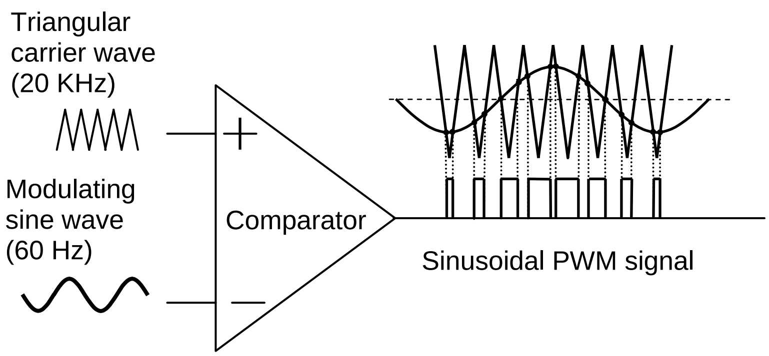

Figure 7 Sinusoidal PWM generation

By the same concept sinusoidal PWM signals can be generated through digital synthesis using a microcontroller. The advantage is that since a microcontroller is needed anyway to implement various measurement and control functions an inverter system needs the PWM signal generation function can be implemented on the same device which leads to a simpler and more cost effective design. To generate a sinusoidal AC voltage we need a timer that has two compare registers: one to set the carrier frequency and the other one to set the duty cycle. The duty cycle modulation can be implemented with a look-up table containing discrete values corresponding to the sine wave amplitude.

Using 8-Bit representation there can be 256 discrete amplitude values that correspond to a full sine wave period for example. Reading and writing the entire table repeatedly to the duty compare register at discrete time intervals, will result in sine modulated PWM signal on the timer output. As previously seen in Figurers 5 and 6, to generate single phase three-wire or three-phase sinusoidal voltages we need to have a six-transistor H-Bridge driven with three PWM signals and their complements. In three-phase inverters the phase voltages are 120 deg out of phase as sown in Figure 8.

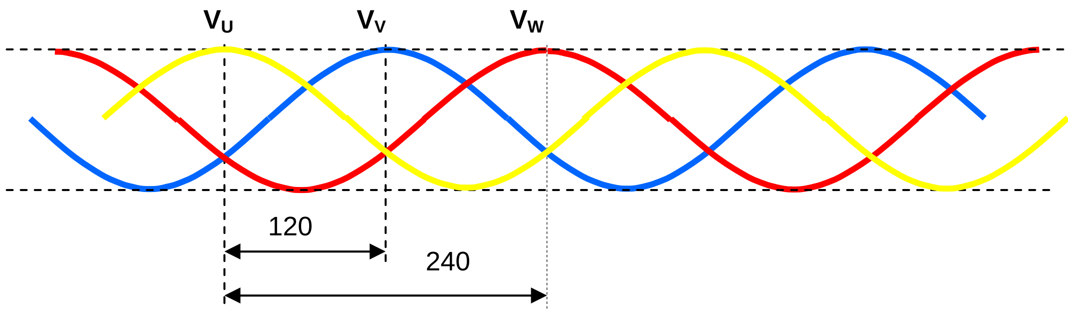

Figure 8 Three phase AC waveforms

In a single phase three-wire system one of the phases is used as the neutral phase. Figure 9 shows the AC voltage waveforms for a single phase three-wire inverter. Two of the phases (L1 and L2) have voltages of the same amplitude but 180 deg out of phase and the third one is kept at a constant level of ½ of the amplitude. If each phase amplitude is 120V the voltage measured between L1 and L2 will be 240V.

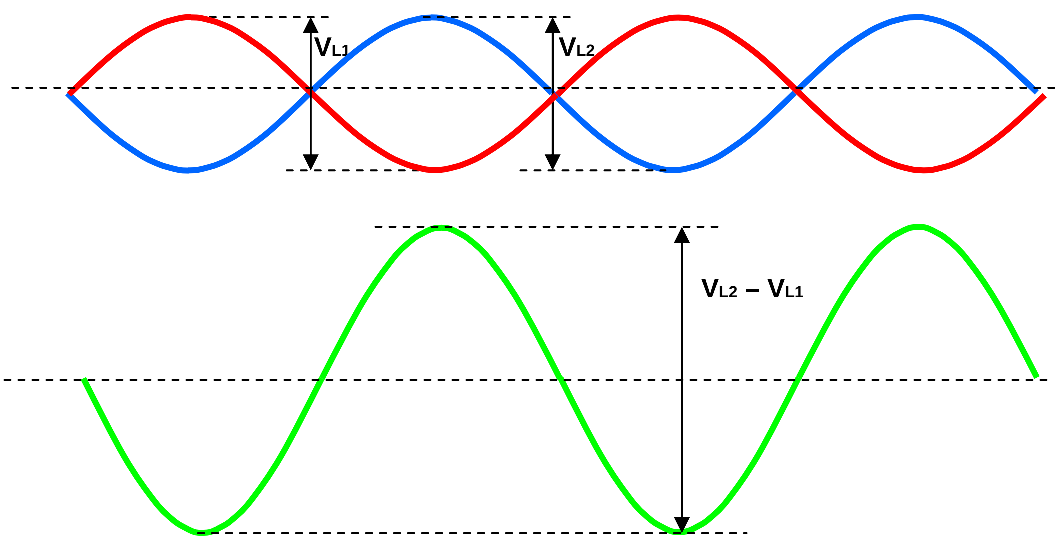

Figure 9 Single phase three-wire AC waveforms

5. Microcontrollers for inverter control

As mention before to generate single channel sinusoidal PWM a timer and a couple of compare registers are is needed. To generate three phases with different PWM duty cycles we need one compare register to set the PWM frequency and one compare registers for each phase. To generate perfect sinusoidal voltages all three signals have to be precisely synchronized. Although general purpose microcontrollers have been used the performance is not as good as when using microcontrollers dedicated for inverter control. These devices have special timers and other peripherals that can offload CPU occupancy and greatly improve performance.

NEC Electronics has a variety inverter control devices called ASSPs (application - specific standard products), ranging from 8-bit and 16-bit @ 20 MHz to 32-bit up to 100 MHz covering pin counts from 30 to 128. These devices are commonly used in three phase induction motor and permanent magnet motor VSDs (variable speed drives), also known as VFDs (variable frequency drives). A simplified inverter timer structure for one of the 32-bit NEC Electronics MCUs is shown in Figure 10.

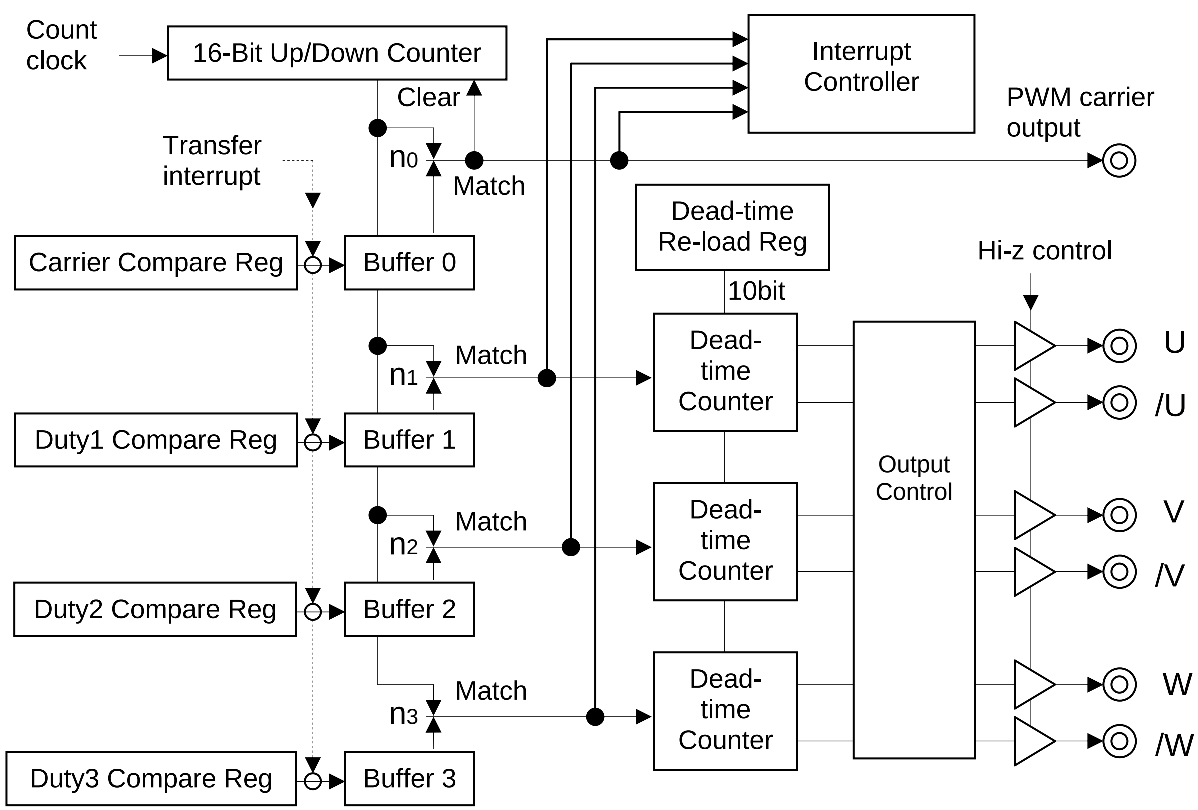

Figure 10 Inverter timer block diagram

The 16-bit timer is configured as an UP/Down counter. A carrier compare register is loaded with a value which sets the PWM carrier frequency. The timer counts up to this value and counts down to 0 repeatedly. Three duty compare registers set the duty cycles.

The reason we use Up/Down counter is to generate center-aligned PWM signals. Center-aligned PWM is key to minimizing the switching noise because switching occurs at different times for each phase. All four compare registers are double-buffered to allow duty cycle change on-the-fly while the timer is running. The new values can be re-written any time but the actual transfer to the internal buffers is automatically triggered by hardware on a transfer interrupt which can be selected from either the timer overflow interrupt also called the valley interrupt or the crest interrupt as illustrated in Figure 11.

When the main counter value matches any of the compare register values, a match signal is generated. In the case of the carrier match the counter is reset and the counting starts from 0 again. Each top and bottom transistor pair is driven with the same PWM signal except that the bottom is driven with the complemented logic level. The block diagram in Figure 10 also shows that each match signal is input to a Dead-time counter. The Dead-tine counter will generate a time delay between the switching time of the top transistor and the bottom one. This is necessary to prevent the top and bottom transistors from being on at the same time and short-circuit the DC bus.

Each compare register match also generates an interrupt that can be used to trigger software processing. The carrier match interrupt can be further “culled” or skipped before being processed to allow flexible control loop timing. The culling rate can be set by the user in 32 steps by software manipulation in a special 5-bit register.

Other interesting feature of the inverter timer is the High-impedance control block. All six PWM outputs can be disabled when fault condition is detected. The High-impedance state can be triggered by external hardware trough a dedicated I/O pin, an internal comparator set-up to monitor the phase voltages or currents, by software or by an internal clock monitor circuit.

Figure 11 shows a timing diagram for the inverter timer. Three independent duty cycles n1, n2, n3 are shown to be transferred to the internal buffers on the transfer interrupt chosen to be the timer overflow interrupt in this case.

As described earlier to generate the sine wave the algorithm needs to calculate the discrete values of a sinusoid and write the to the duty compare registers at precise time intervals. These new PWM values are shown as n1’n2’ and n3’ and will become active on the next transfer. The entire inverter timer operation is automatic and it is independent from the CPU. The only thing the CPU needs to do is to recalculate the new duty cycles and rewrite the registers. For a 50 or 60 Hz sine wave with 256 points per period the rewrite cycle is 65.078 to 78.125 us.

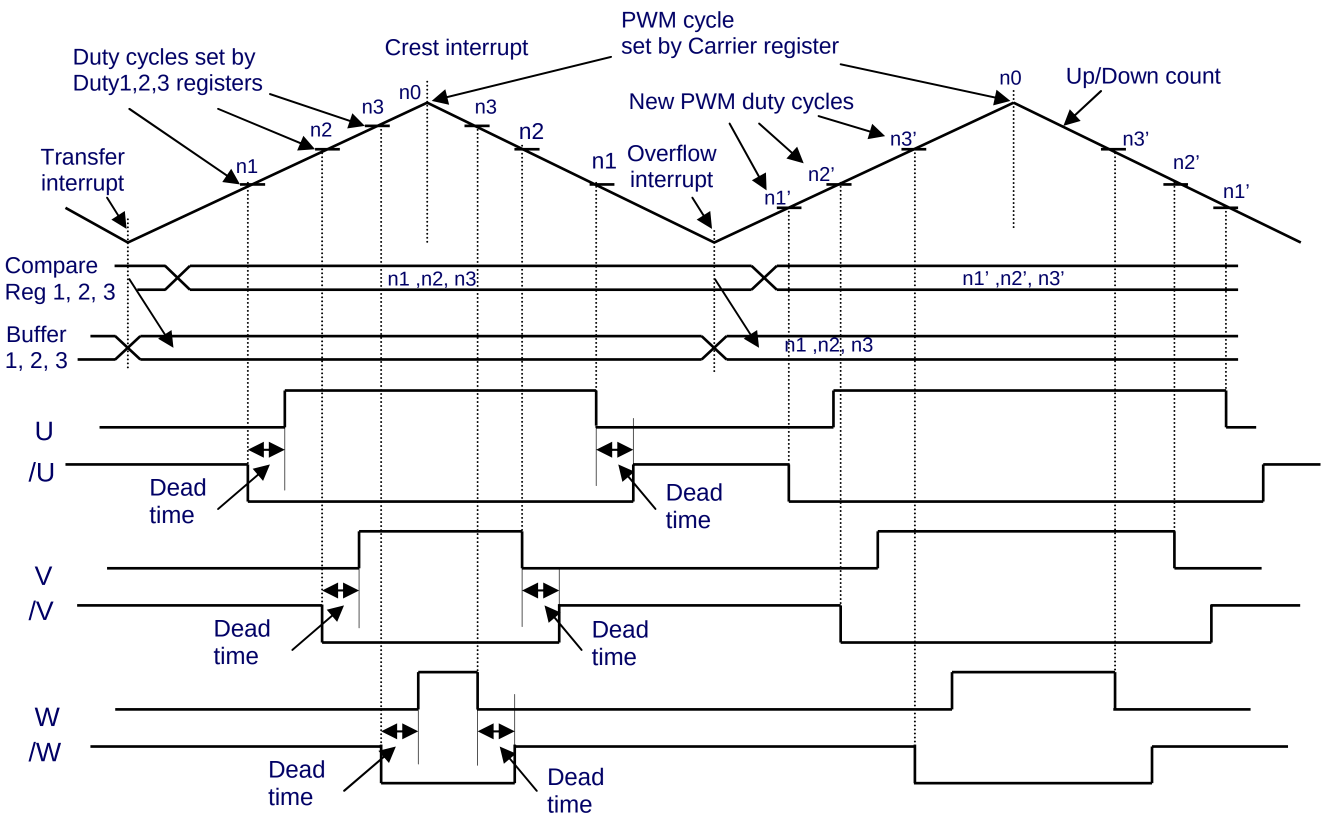

Figure 11 Inverter timer waveforms

Inverter applications require fast and accurate voltage and current measurement. All NEC Electronics inverter ASSPs are equipped with fast 10-bit or 12-bit ADC and one of the built-in features is the synchronization with the inverter timer. Some of the 32-bit ASSPs have embedded Operational Amplifiers with software adjustable gain and internal comparators with adjustable threshold levels. The benefit of having embedded analog is to improve noise immunity as well as to reduce total system cost.

6. Solar inverter system solutions

As described in the previous chapters the main control components of a solar inverter system are: the battery charge controller, the DC/DC boost converter and the power inverter. All of these blocks need microcontroller support. Depending on the system architecture these components can be separate units which can then used to build a modular system or some if not all can be combined and integrated in one unit. The modular approach has the advantage of offering flexibility in system layout and perhaps scalability. An integrated solution on the other hand can be more cost effective and offer the same scalability benefits.

For most residential systems all the components are in close proximity of each other, so that a central control makes more sense. For a system designer the issue of bandwidth and peripheral support will be deciding factors when choosing the right microcontroller. In the following chapters will discus two examples of integrated systems: one using two microcontrollers which we will call a two-chip solution and one using a single-chip solution.

6.1 Two-chip inverter system

In the following we will examine a system implementation with two microcontrollers. One will be responsible for the battery charge controller with MMPT and the other one with the DC/DC boost converter and DC/AC power inverter. Figure 12 shows the block diagram of this example with the battery charge controller using NEC Electronics 78K0/IY2 MCU, which is the 30-pin version of the 78K0/Ix3 family. The IY2 MCU has two internal operational amplifiers and three comparators making it one of the best choices for a cost-effective solution. To implement the battery charger function with MMPT, the on-chip resources used are the 5-channel 10-bit A/D, the internal operational amplifier, one comparator and the 16-bit timer X0. The solar panel voltage, the DC/DC buck converter output voltage, the solar cell temperature and the battery temperature are monitored through resistor dividers and directly connected to the A/D inputs. The charging current is sensed through RS1 on the low side and input to the internal operation amplifier with the gain adjusted by external resistors. The output of this operational amplifier is connected to the input of one of the internal comparators to control the PWM timer output. The timer runs from a 40MHz internal clock, and it generates the PWM signal to drive the MOSFET gate through a low-side optically isolated driver such as the NEC Electronoics PS9552.

The second stage containing the DC/DC boost converter and DC/AC power inverter is implemented with the 32-bit V850E/IF3 microcontroller. The IF3 device is a dedicated inverter ASSP, and it also contains operational amplifiers and comparators. The DC/DC boost converter increases the battery voltage of 24V, 36V or 48V to 350V – 380V DC needed for the inverter stage. The minimum resources used on the IF3 MCU are two 16-bit timers TAB0 and TAB1, two 12-bit analog to digital converters

ADC0 and ADC1, one internal operational amplifier, one set of comparators, one interrupt input and one general purpose I/O.

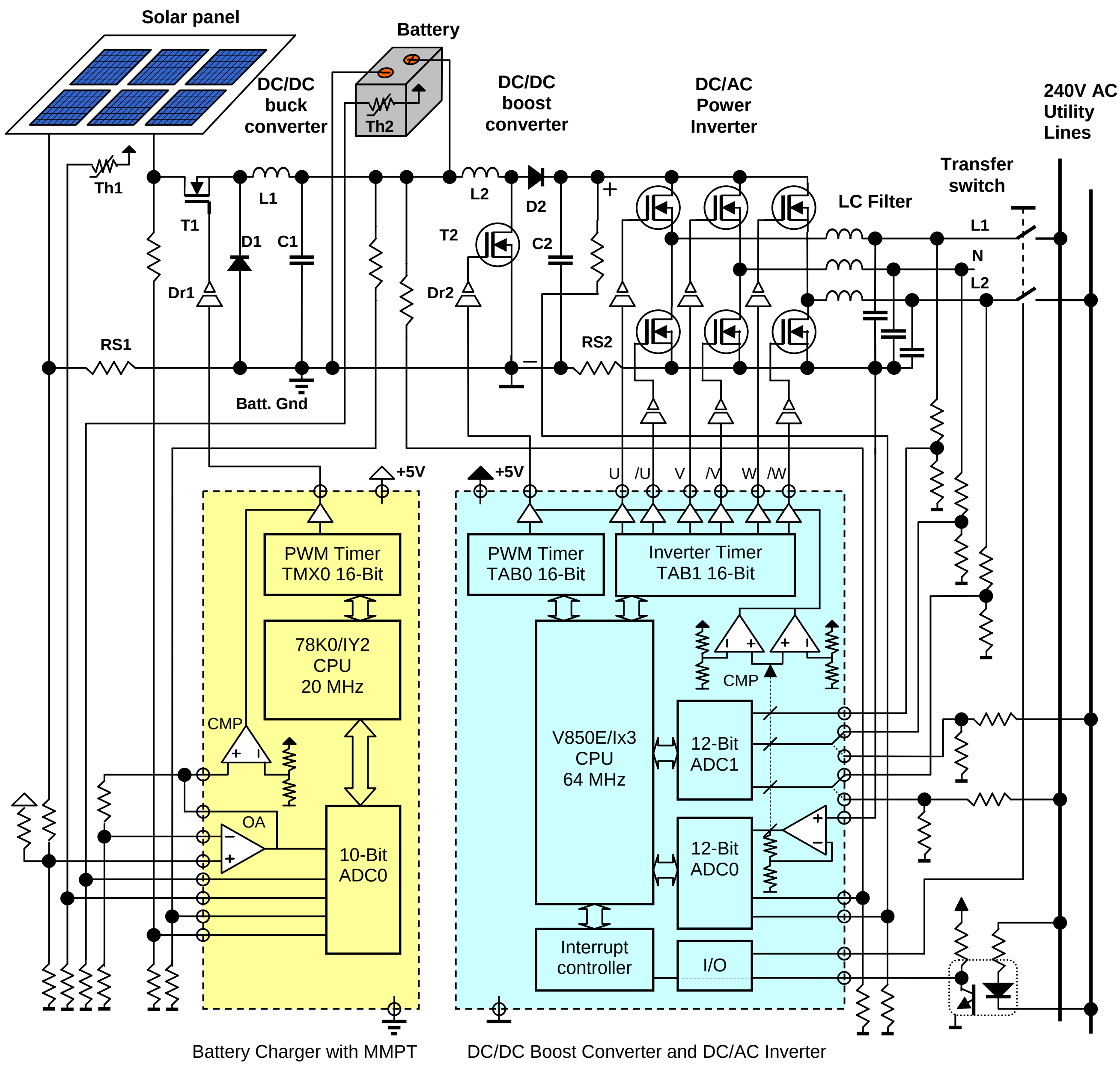

Figure 12 Two-chip solar inverter solution

The battery voltage and the DC/DC converter output voltage are scaled through resistor dividers and are input directly to ADC0. The inverter DC current is sensed with RS2 and amplified by the embedded operational amplifier with internally adjustable gain. The inverter output voltages are monitored by ADC1 and the grid connect transfer switch is controlled by a general purpose I/O pin. Before connecting to the grid, the controller needs to know if the utility line voltages and frequency are with in the accepted limits. The line voltages are monitored by ADC1 and the frequency by the an interrupt input through an optocoupler. Safety is very important in inverter systems because high voltages and currents are present. The internal comparators monitor and detect any over-current or overvoltage and can shut down the PWM both the DC/DC converter output as well as the inverter bridge control. For additional safety, the bridge transistor gates are controlled with optically isolated drivers such as the NEC Electronics PS9552.

6.2 Single-chip inverter system

In the following, we will examine a single chip solution built around the NEC Electronics V850E/Ix4 microcontroller. The reason we chose this device is due to the abundance of embedded analog- and special inverter timers and other peripherals, which allows the implementation of a the entire solar power inverter system with only one microcontroller. The block diagram of the V850E/Ix4MCU is shown in Figure 13.

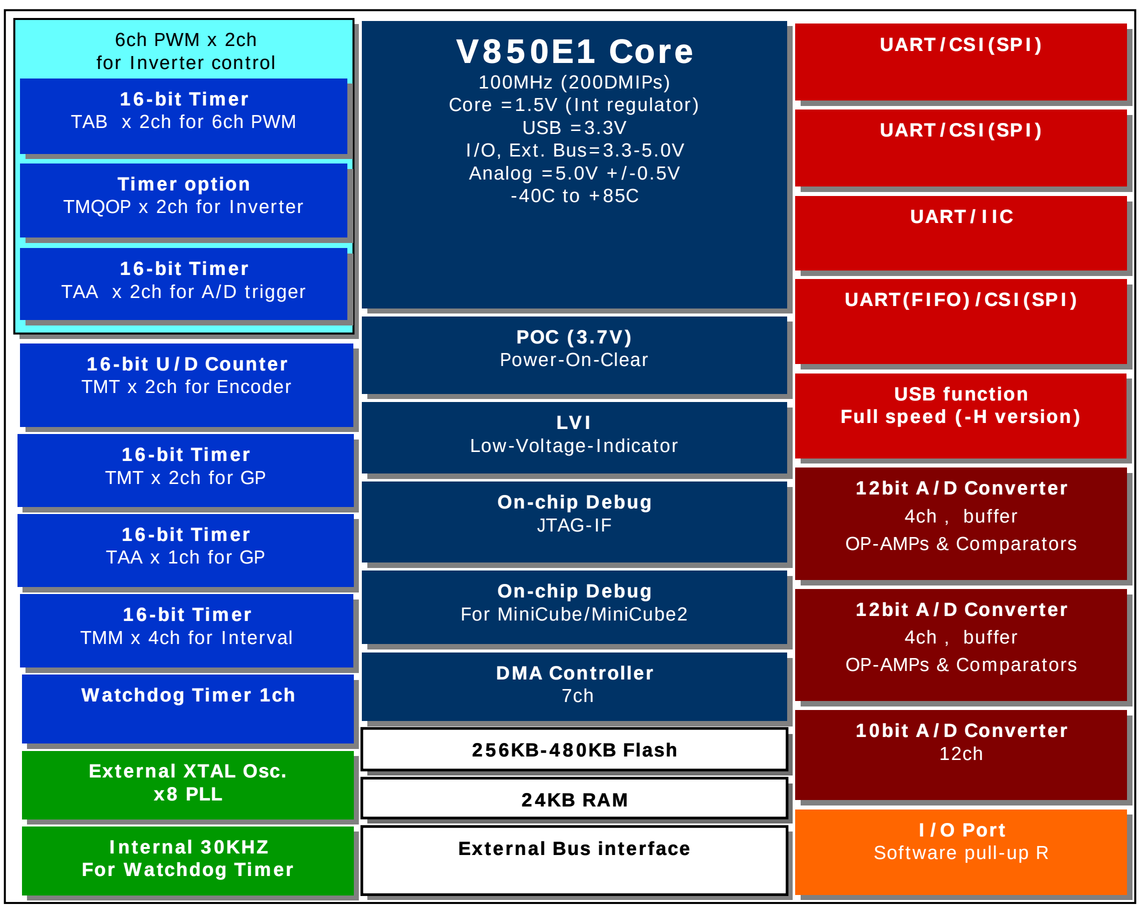

Figure 13 V850E/Ix4 mictocontroller

The V850E/Ix4 MCU is equipped with two sets of inverter peripherals making it very attractive solution for this type of application. The V850E/Ix4 MCU also has the right amount of embedded analog to interface all necessary signals from all the major components of a solar inverter system: the DC/DC buck converter for battery charging with maximum power point tracking controller, the DC/DC boost converter, the DC/AC inverter and the power line monitoring.

Figure 14 shows a system block diagram of the solar inverter with the V850E/Ix4 microcontroller. The first stage containing T1, L1, D1 and C1 is the maximum power point tracking battery charger. Its role is to ensure an optimum power transfer from the solar panel to the battery and inverter regardless of the illumination, ambient temperature and panel orientation. The solar panels output voltage depends on the outside temperature throughout the year. In winter days when the solar activity is lowest the diminished output capacity is compensated by the fact that when temperature is lower output power increases by up to 10% compared with the hottest days in the year. Panel temperature is monitored with Th1 and the MMPT algorithm is adjusted accordingly. The DC/DC buck converter battery charger is implemented with T1, L1, D1, C1. The second stage containing T2, L2, D2, C2 is the DC

Three of the internal operational amplifiers are used to monitor two load currents and two temperatures. The internal comparators are used to detect load over-current and power line voltage conditions. The gains can be set to x1 or from x2.5 to x10 in 13 individual steps. An internal comparator is used to detect over-current or short circuit and shut down the gate output for the boost converter as well as for the inverter bridge in case of a faulty condition.

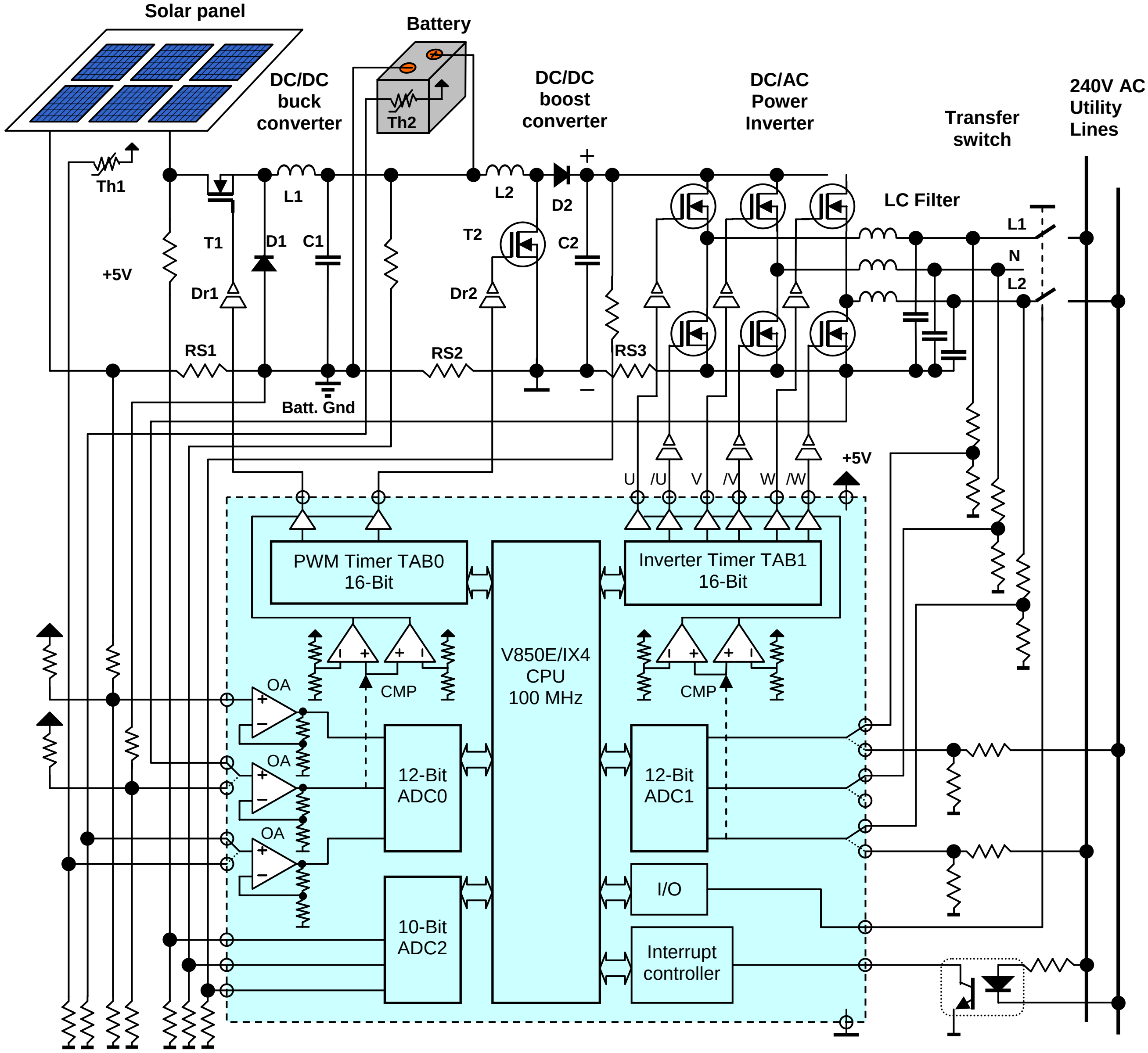

Figure 14 Solar inverter system

7. Summary

Solar power inverters are the most attractive alternative clean energy solutions that can greatly contribute to reducing the need for fossil fuel burning and offer greater independence in flexibility in production and distribution. Throughout this application note we examined in some detail the operation and control of a solar power inverter system and proposed two possible solutions.

When choosing microcontrollers for solar power inverters designers should consider using dedicated devices that have the advantage of integrating a number of the peripherals needed to control most if not all the major components. In our two-chip solution we showed how we can use a low-cost 8-bit microcontroller to implement the battery charger and MMPT controller and a high performance 32-bit RISC microcontroller for the DC/DC boost converter and the DC/AC power inverter. Due to the embedded operational amplifiers and comparators we were able to reduce the external component count, reducing the total bill of material and PCB space which leads to a more compact and economical design.

The second example is a further integration of the functions and features needed to be supported in a solar power inverter system. By using a very special inverter ASSPs we were able to implement everything in one microcontroller. The V850E/Ix4 device is a high-performance, 32-bit RISC microcontroller with powerful analog and digital peripherals. By employing a single-chip solution, we were able to further reduce component count and PCB real estate. By having one firmware controlling both the battery charger and the inverter, we can further reduce the development cost and maintenance.

For more information, contact:

NEC Electronics Corporation
1753, Shimonumabe, Nakahara-ku,
Kawasaki, Kanagawa 211-8668,
Japan
Tel: 044-435-5111
http://www.necel.com/

[America]

NEC Electronics America, Inc.
2880 Scott Blvd.
Santa Clara, CA 95050-2554, U.S.A.
Tel: +1-408-588-6000
U.S. only: 1-800-366-9782
http://www.am.necel.com/

[Europe]

NEC Electronics (Europe) GmbH
Arcadiastrasse 10
40472 Düsseldorf, Germany
Tel: 0211-65030
http://www.eu.necel.com/

Hanover Office
Podbielski Strasse 166 B
30177 Hanover
Tel: 0 511 33 40 2-0

Munich Office
Werner-Eckert-Strasse 9
81829 München
Tel: 0 89 92 10 03-0

Stuttgart Office
Industriestrasse 3
70565 Stuttgart
Tel: 0 711 99 01 0-0

United Kingdom Branch
Cygnus House, Sunrise Parkway
Linford Wood, Milton Keynes
MK14 6NP, U.K.
Tel: 01908-691-133

Succursale Française
9, rue Paul Dautier, B.P. 52180
78142 Velizy-Villacoublay Cédex
France
Tel: 01-3067-5800

Sucursal en España
Juan Esplandiu, 15
28007 Madrid, Spain
Tel: 091-504-2787

Tyskland Filial
Täby Centrum
Entrance S (7th floor)
18322 Täby, Sweden
Tel: 08 638 72 00

Filiale Italiana
Via Fabio Filzi, 25/A
20124 Milano, Italy
Tel: 02-667541

The Netherlands
Limburglaan 5
5616 HR Eindhoven
The Netherlands
Tel: 040 265 40 10

[Asia & Oceania]

NEC Electronics (China) Co., Ltd
7th Floor, Quantum Plaza, No. 27 ZhiChunLu Haidian
District, Beijing 100083, P.R.China
TEL: 010-8235-1155
http://www.cn.necel.com/

NEC Electronics Shanghai Ltd.
Room 2509-2510, Bank of China Tower,
200 Yincheng Road Central,
Pudong New Area, Shanghai P.R. China P.C:200120
Tel: 021-5888-5400
http://www.cn.necel.com/

NEC Electronics Hong Kong Ltd.
12/F., Cityplaza 4,
12 Taikoo Wan Road, Hong Kong
Tel: 2886-9318
http://www.hk.necel.com/

Seoul Branch
11F., Samik Lavied'or Bldg., 720-2,
Yeoksam-Dong, Kangnam-Ku,
Seoul, 135-080, Korea
Tel: 02-558-3737

NEC Electronics Taiwan Ltd.
7F, No. 363 Fu Shing North Road
Taipei, Taiwan, R. O. C.
Tel: 02-2719-2377

NEC Electronics Singapore Pte. Ltd.
238A Thomson Road,
#12-08 Novena Square,
Singapore 307684
Tel: 6253-8311
http://www.sg.necel.com/

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