GYAN GANGA
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Gyan Ganga
Institute of Technology and Sciences

TECH ADVISOR

2021-22

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Contact Us - +91 942 53 23089, +91 982 61 18736

Location - P.O. Tilwara Ghat, Bargi Hills, Jabalpur, Madhya Pradesh Pin No. - 482003

Connect with us:- LinkedIn twitter www.ggits.org

ABOUT THE DEPARTMENT

Department of Electronics & Communication Engineering (EC) of GGITS, Jabalpur offers B.Tech. in Electronics & Communication Engineering with an intake of 120 students and M.Tech. in Communication system with an intake of 18. The department has excellent infrastructure as well as well equipped laboratories so that the students come out with knowledge of latest cutting edge technology in both software and hardware. The department has been accreditated with excellence by National Board of Accreditation (NBA). The department has well experience dedicated faculty members with different specializations.

VISION OF THE DEPARTMENT

To be center of excellence in teaching-learning and employability in various fields of Electronics and Communication Engineering to produce globally competent, innovative and socially responsible citizen.

MISSION THE DEPARTMENT

- To offer high quality graduate and post graduate programs in Electronics and Communication with strong fundamental knowledge and to prepare students for professional career or higher
- studies.
  To discover and disseminate knowledge through learning, teaching, sharing, training, research, engagement and
- creative expression.
  To foster spirit of innovation and creativity among students, faculty and staff, promote environment of growth, participation in conferences, technical and community services and lifelong learning for all.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO 1: The graduates will have strong fundamentals in mathematics, science and engineering so that they can meet industrial and global challenges and excel in the field of Electronics and Communication Engineering and also will be motivated to excel in professional career and higher education.
PEO 2: The graduates will have good scientific and engineering breadth to analyze, design and develop systems/ components, problem-solving skills and aptitude for innovation.
PEO 3: The graduates will exhibit leadership qualities with strong communication skills, competence to function effectively in multi-disciplinary orientation teams, capability to assess and relate engineering issues to ethical, environmental and broader societal context.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO 1: Understand the fundamental and advanced concepts of Mathematics, Science & Engineering and apply it to design and develop Electronics and Communication Engineering applications in the field of communication system, signal processing, embedded systems and VLSI Design.
PSO 2: Learn and comprehend continuously the technological advancements with the usage of modern design tools to analyze and design variety of complex Electronics and Communication Engineering applications.
PSO 3: Possess/Acquire the skills to communicate in both oral and written forms with good Leadership, Managerial skill to work either independently or as a team, demonstrating the practice of professional ethics for sustainable development of society.

MESSAGE FROM THE CHAIRMAN

I am elated at the publication of college magazine for the academic year 20121-22. I sincerely hope that the magazine proves to be an enjoyable and useful apparatus in the hands of both students and teachers of the college. I am also confident that it will serve as a source of inspiration for the teachers as well as the students to contribute articles regularly to the magazine in future. I whole-heartedly congratulate the HOD, Editors and the committee members on their successful endeavour to bring out the magazine.

MESSAGE FROM THE PRINCIPAL

It takes me great honour in congratulating the students who have contributed for the current year's Tech Advisor magazine Acknowledging the fact that the magazine is completely created and designed by the students, I really hope this would kindle a spark in the minds of the students who are yet to contribute towards the progress of the Tech Advisor initiative in the upcoming years.

MESSAGE FROM THE HOD

Tech Advisor is a communication link between faculty members and students within and outside the department. It reports about recent development and areas of thrust in the field of Electronics & Communication Engineering. Tech Advisor tries to bridge the gap between academic and actual mode of working in the industry by providing articles on various topics of industry. At the same time magazine also serve as a knowledge booster and a helping hand to our students. We also make aware our students with the general issues related to environment, ecology, economy and rest of the society. It also helps to bring together all the students and faculty members to the same platform to share numerous ideas to think upon. Students can also share their thoughts on a particular matter as well as they can also contribute any research by means of this channel. It can be easily concluded that our departmental magazine is not only information provider but also groom the overall personality of our students.

EDITOR'S DESK

The creative minds of the Electronics and Communication department of Gyan Ganga Institute of Technology and Sciences have come together to present what they have always wanted to and we congratulate every student who has given their contribution. They can't be appreciated enough and we can't explain how difficult it was to compile all their accomplishments into a single magazine. We take pride in showing you of how our very own GGITians have imaginations which spread across the horizons. We would like to thank the Management and all the staffs who have supported the 'Tech Advisor' initiative and for having trust in the Editorial board by giving us full freedom to choose the contents and design for out magazine. The magazine should serve as a pillar of motivation for every other student who is yet to emerge as an Achiever and to carry the legacy of Tech Advisor. The students who follow in the next academic years, we advise you to do the same. Go Mad, Be Productive but at the same time Be Creative!

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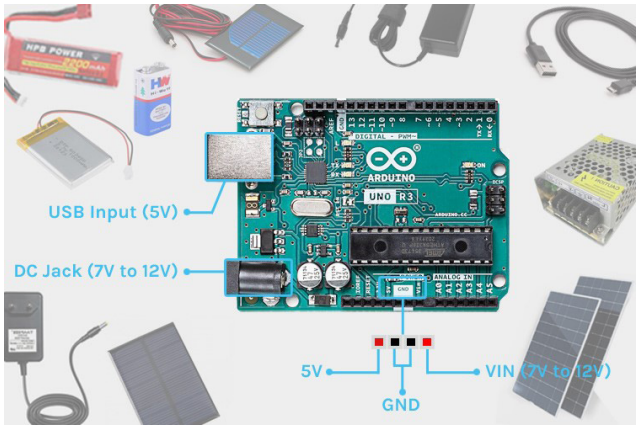
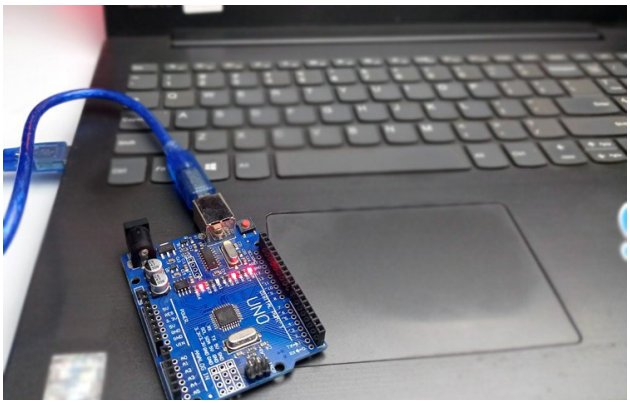
DIFFERENT WAYS TO POWER YOUR ARDUINO BOARDS

We use Arduino boards in many of our projects. Most of the time we will power it through the USB port. But, that's not the only way to power an Arduino. In this article we will learn about the four different ways to power an Arduino UNO board. While making any projects, knowing these techniques will be handy in instances when flexibility with regards to the power supply is required.



1. USB Powered Arduino

The USB port of the Arduino Uno can be connected to an USB device or port that can provide a stable 5V output like a computer or power bank or USB charger, etc. By using the USB cable, you can eliminate the need for an external power source, while debugging if your total circuit's current requirement is less than that of the computer's USB port can provide. Not only that, you can use it with any standard power bank which makes your project totally portable. A USB 2.0 port can provide current up to 500mA and it is more than enough for an Arduino UNO.



Depending on the Arduino board, the type of USB connector may vary. For example, Arduino UNO have a USB type B connector, meanwhile, Arduino nano has the UCB mini-B connectors. Here is the USB connector types for all the Arduino boards.

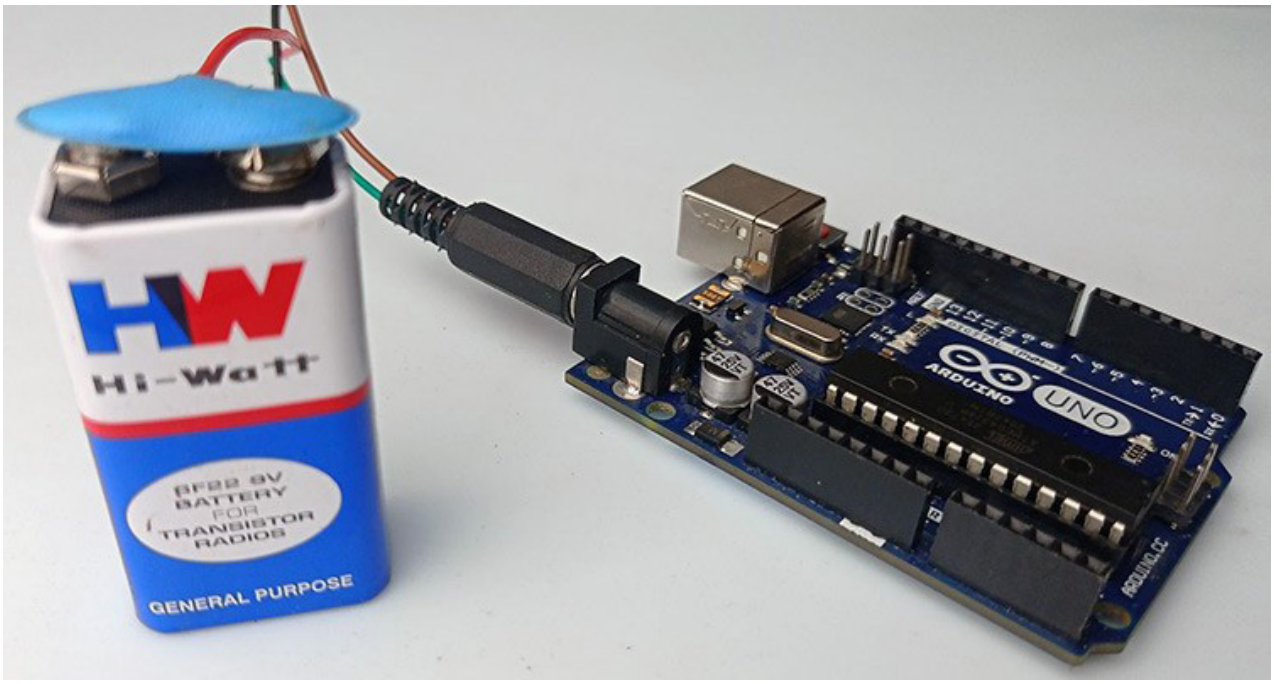
USB Connector	Arduino Boards
USB Type B	Arduino UNO, Mega, Uno Wi-Fi
USB Mini B	Arduino Nano
Micro USB	Arduino Leonardo, Mico, Nano Every, Nano BLE, Mkr Zero, Due, MKR Vidor 400, Arduino Zero, Nano IoT, MKR FOX 1200, MKR WAN 1300/1310, MKR GSM 1400, MKR Wifi 1010, MKR NB 1500, Nano RP2040 Connect
USB Type C	Arduino Portenta H7

Here are the typical ratings for the USB input.

Specification	Value
Voltage	5V
Current	500mA (Typical USB Port Rating)

2. Using Arduino Power Jack

Arduino Uno and all many other big form factor Arduino boards are equipped with a standard 2.1mm DC power jack. Arduino Uno accepts 7-12V dec through this port and the onboard voltage regulator regulates it down to the required 5 and 3.3V. The centre pin is positive and the outer sleeve is grounded. You can use any 12V AC-DC adapter with proper out voltage and proper connector to power your Arduino board. It is more convenient when deploying your project where it's not constantly monitored.



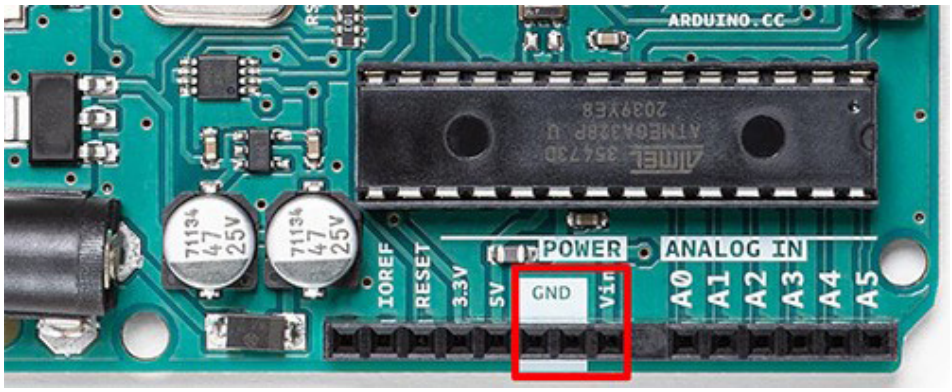
You can also use a 9V battery to power the Arduino Uno, with the help of a snap-in connector with a DC Barrel Jack. This will allow us to use the Arduino as a portable device. It's really helpful when there is no mains voltage available. And since the 9V batteries are cheap and easily available, this option will help to do projects that are meant to be operated in remote areas.

Here are the typical ratings for the DC jack input.

Specification	Value
Voltage	7-12 (Recommended)
Current	800mA

3. Using the Vin pin on Arduino

You can power the Arduino through the Vin pin. Vin pin supports an input between 7-12V. It is directly connected to the positive rail of the DC barrel connector. Same as the barrel connector Vin pin also utilizes all the safety measures onboard.

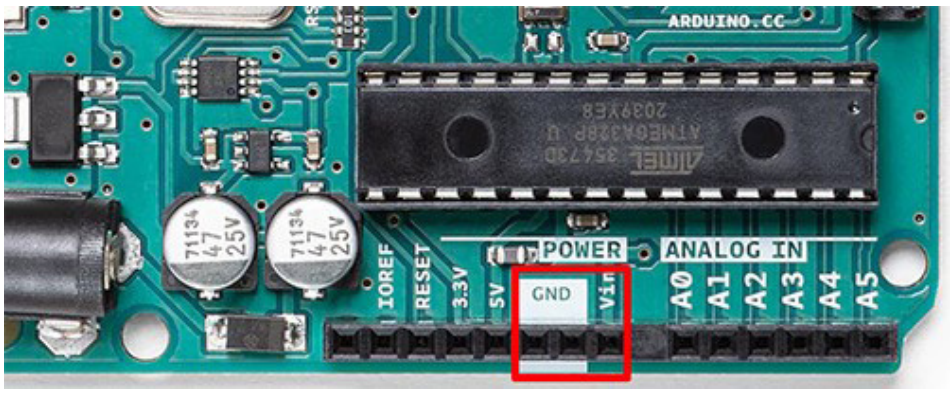


Here are the typical ratings for the VIN input.

Specification	Value
Voltage	7-12 (Recommended)
Current	800mA

4. Directly Powering the Arduino on 5V pin

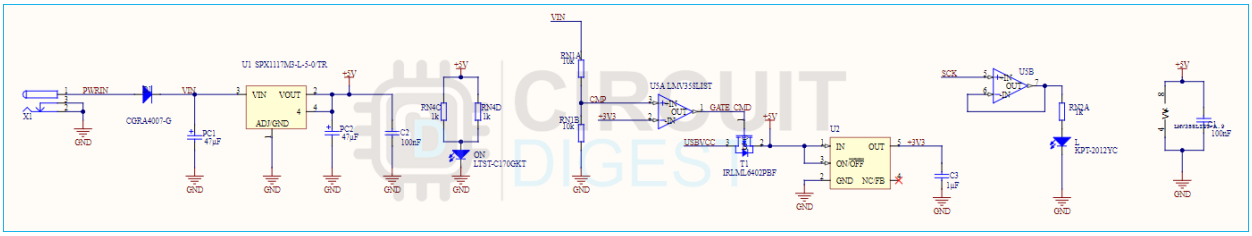
Yes, you can directly power an Arduino from a 5V source. But keep in mind that the 5V should be steady and regulated. The 5V pin bypasses all the safety measures on the board, including the fuse, reverse polarity protection, input power select and voltage regulators. So, if the input exceeds the 5V (5.5V maximum) or the polarity is reversed, the board can be damaged. It is recommended to be very careful while using this method. The 5V pin is located between the 3.3V and GND pins.



Specification	Value
Voltage	5V
Current	Not Limited

Is it safe to Power Arduino with 12V and USB cable at the same time?

You might wonder what will happen if we connected the USB supply to the USB port and the 12V supply to the DC barrel jack of the Arduino at the same time. Is it safe? Yes, it is. The Arduino Uno board has a clever design for the power input selection. Here is the schematics of the power section of an Arduino Uno. If you look at this, you can find a power selection circuit that is formed around a comparator circuit based on an LM358 OpAmp. When a supply is present in the DC barrel Jack the comparator circuit will turn off the P-Channel MOSFET, which will cut off the USB supply from the board. When there is no other power input available the MOSFET will be turned on and the Board will be powered from the USB.



How to Power Arduino Boards using a Battery?

If you don't want your project to depend on the main's power, you can simply connect a battery directly to the DC barrel jack or the Vin pin, as long as it is within the input voltage limit and it can provide enough current. For example, you can directly connect a 9V 6F22 battery to the Arduino through the barrel jack using a 2.1mm connector or directly to the Vin pin using jumper cables. these are the commonly recommended methods to power an Arduino.

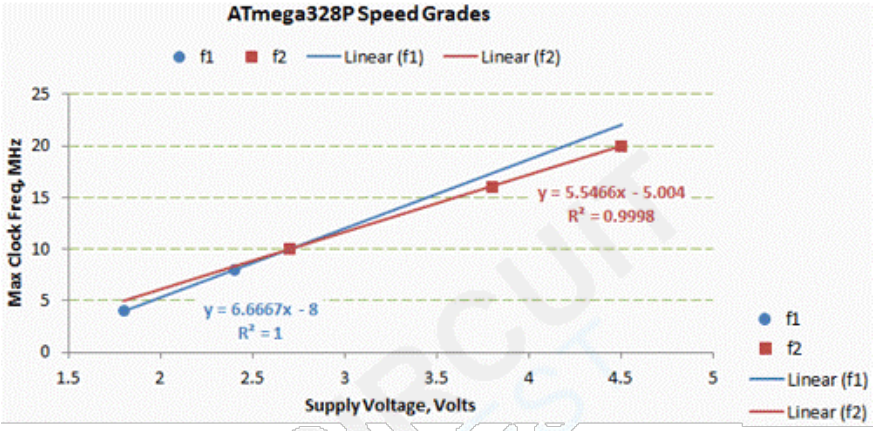
How to Power Arduino boards with a 3.7V lithium battery?

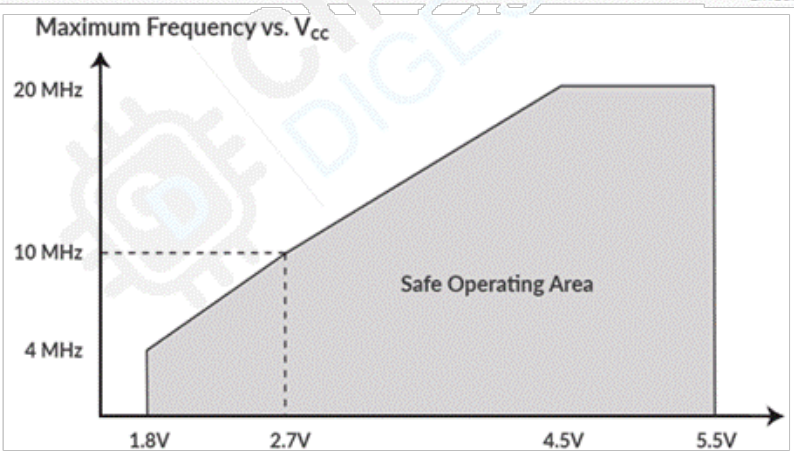
You might have thought that since most electronics nowadays run-on Li-ion or Li-po batteries, can we also power an Arduino with a 3.7V Li-Ion or Li-po battery? As a matter of fact, you can. The Arduino will just work if you connect a 3.7V battery to it. But is it a recommended way? I would say no. Most microcontrollers have a recommended working voltage with respect to the operating frequency. If you want to run an Arduino on a 3.7v cell, it is recommended to reduce its clock frequency, to reduce silicon degradation and performance issue. If you are going to power an Arduino board with an Atmega328P microcontroller, like Arduino Uno or nano, it's better to run it at a safe clock rate of 8MHz instead of the 16MHz, which is the normal working clock frequency of these chips. You can find that safe voltage–frequency area for ATMega328P in the below section. Some boards come with a Li-Po (Lithium-ion Polymer) battery socket that supports this kind of battery natively.

For example, MKR boards (except MKR FOX and WAN 1300) come with this feature. For those boards, you can connect the 3.7V battery directly without worrying about the clock frequency.

Can Arduino boards work on 3.3V?

The short answer is Yes. Theoretically, the ATMega328P will work with 3.3V. But its clock speed will be reduced. And not only that at 3.3V the manufacturer recommends using an 8MHz crystal instead of the 16MHz found on the Arduino. Here is the Maximum Frequency vs. VCC curve.

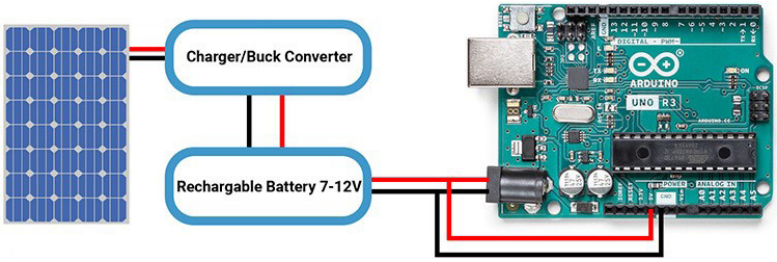




So, if we want to run Arduino UNO on 3.3V, we must reduce its clock to avoid any performance instability.

Power the Arduino with Solar Panel

Yes, you can power an Arduino from a solar panel as long as the voltage and current output are correct. The recommended way is to use a charger to charge a battery from the solar panel and to power the Arduino from the battery. So that even if at night or with low sunlight your projects will work just fine.



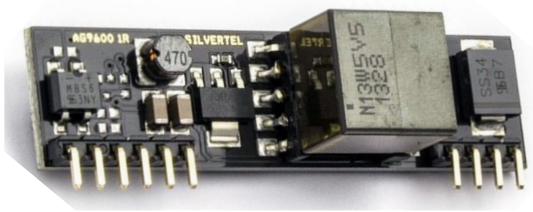
In this setup, the voltage from the solar panel is going to the charger module and the charger module charges the battery. Then the battery is connected to the DC barrel connector or the Vin pin of the Arduino. This setup is good for projects in remote areas where the power source is stable or unavailable. For example, this will be the perfect way to power a 24x7 monitoring station or beacons.

So, what's the best way to power up Arduino?

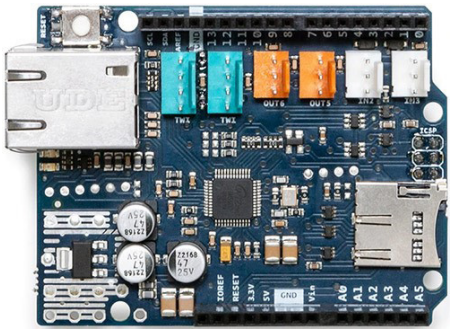
The best way to power an Arduino would be using the DC barrel jack or the Vin pin. So that we can take advantage of all the built-in safety features. But depending on your situation or needs you may select whichever option is best for you. For example, in your project there already all the voltage regulation systems are implemented, in that case, you can power up your Arduino through the 5V pin. For a project where the backup is required in case of power failure or if the power is unavailable use the solar panel with battery and charger.

The advanced way to Power an Arduino – PoE

Yes, you heard right you can power an Arduino UNO using PoE (Power over Ethernet). Most network device provides PoE support, which eliminates the need for a separate power source for any device that's connected to the ethernet port. To use this capability, we will be using the Arduino Ethernet Shield 2 PoE module.



PoE Module:



Arduino Ethernet Shield 2:

This will allow us to power our Arduino project directly from any PoE supported ethernet shield. The PoE module is designed to extract power from a conventional twisted-pair Category 5 Ethernet cable.

SURUBHI KHURASIYA
0206EC181097
(B.E.-7th Sem)

A DETAILED COMPARISON OF POPULAR LI-ION BATTERY CHEMISTRIES USED IN ELECTRIC VEHICLES

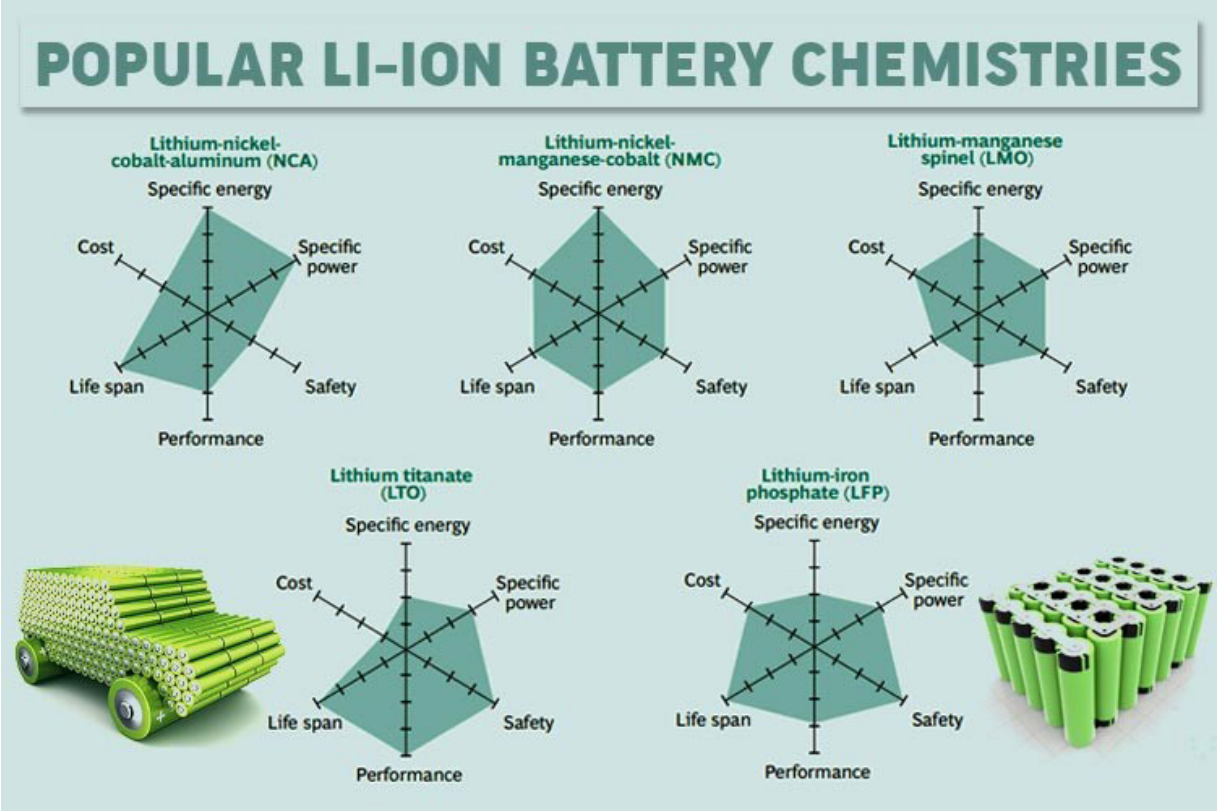


Figure: Comparison of Popular Li-ION Battery Chemistries

Cells have been used for storing energy from time immemorial, from a Baghdad battery, which dates back to 250BC to newer technology such as a hydrogen fuel cell, that just gives water as a byproduct, batteries have come a long way. A group of cells when connected together is called a battery.

Batteries are touted as the future of energy storage for Electric Vehicles. Even the first cars, made in the year 1842 were powered by batteries, which is almost 2 decades before the invention of Internal combustion engine vehicles but the lack of range and slow charge rate caused the decline of Electric Vehicles in the 20th century. The growing environmental concern due to climate change has forced us to move towards renewable energy and adopt battery energy storage systems and the research and development of battery technologies kick-started.

In a country like India, more than a quarter of total pollution is caused due to automobiles. Till date the adoption of Electric Vehicles (EV) could not take off due to range anxiety, price, lack of infrastructure, and lack of choices. The research and development in Li-ion batteries in recent years have paved the way for EVs across the globe. We have previously discussed the basics of electric vehicle batteries in general. In this article we will be learning about different Li-ion chemistries, their advantages and disadvantages and compare them with few other rechargeable batteries.

Primary Cell and Secondary Cell

Primary cells are single-use, non-rechargeable cells, the ones we use in our TV remotes, wall clocks, etc. These are considerably cheaper while having high energy density, which means that they are smaller, weigh less and are more cost-effective. This makes them ideal choice for applications that require lower amount of energy as it helps cut down the cost as well as the weight of the final product.

Secondary cells are energy storage devices that can be reused multiple times. They can perform reversible cell reactions that allow them to recharge, by just reversing the direction of the current. Albeit being more expensive than the primary cells, they can be used multiple times, thus making them a better choice for energy storage applications that require a constant replenishment of energy, such as mobile phones, smart-watches, Electric vehicles, or large Battery Energy Storage systems for homes or discoms, etc.

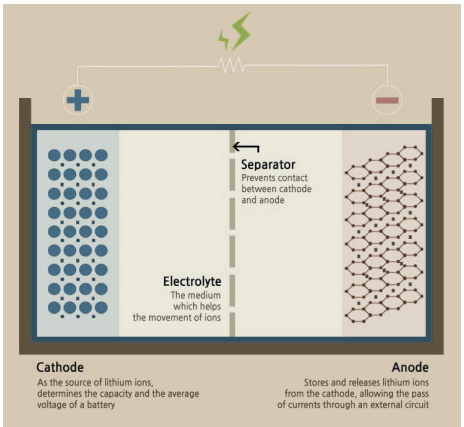
There are a lot of different types of secondary cells available in the market, there are multiple variants of Lithium-ion cells, Nickel cells, Lead-acid batteries, hydrogen fuel cell, etc., all these batteries have their pros and cons. In this article, we will focus only on different chemistries of Li-ion Batteries.

Li-ion Cell

Lithium-ion cells are rechargeable cells, they use lithium as one of the key components in the construction of the cell. The development of Li-ion cells started in the early 70s, and their advancement and potential to catapult the energy storage systems making the adoption of EV's a reality caused its inventors to win a Nobel Prize in Chemistry in 2019. These are rechargeable cells commonly used in portable electronics to something as large as Discoms for storing energy produced from renewable energy. There is a tremendous amount of research going on in the Li-ion batteries which cause the capacity of battery to increase drastically in the coming future. In the past 3 decades, the cost of battery has decreased by 97% and since the last decade, it has fallen by 88%.

Components of Li-ion Cell

Like any other cell, Li-ion cells are also made up of different components. These internal components help in shaping the features and other characteristics of a Li-ion cell. The Li-ion cell has 4 main components that are Cathode, Anode, Electrolyte, and Separator. The image below shows the different components of a Li-ion cell.



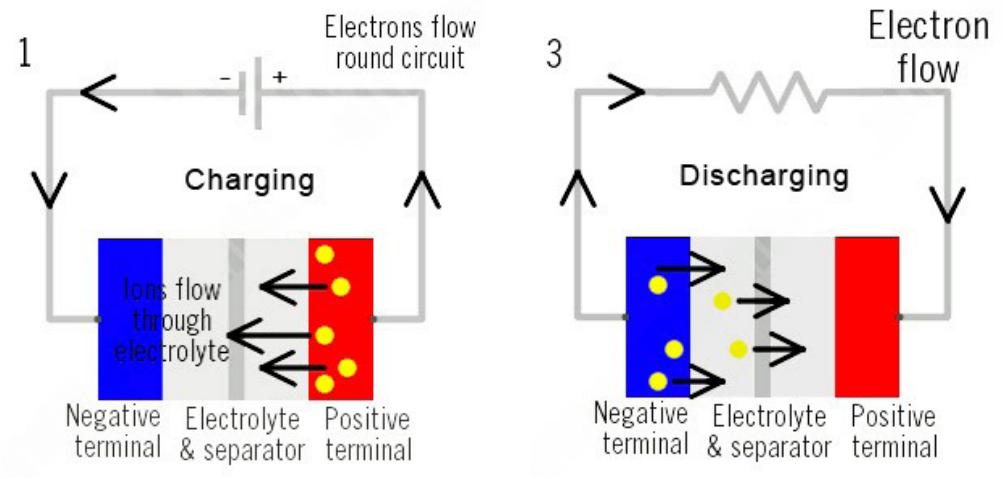
Cathode:

The material used in the cathode determines the capacity and voltage of Li-ion battery. This material is called the active material. The active material plays a crucial role in the chemical reaction in the battery which causes the flow of current. The capacity of a cell depends on the size of the active material at the cathode, i.e. for higher capacity of the cell, we need to have bigger cathodes. Meanwhile, the voltage of the cathode depends on the element used as a cathode.

The nomenclature of the battery usually depends on the cathode, like a Lithium-ion battery has a cathode made up of Lithium. But because lithium is highly reactive and unstable making it difficult to contain and use directly, therefore a combination of lithium and oxygen is used as a cathode.

Anode:

Similar to the cathode, an anode is the other electrode, which is also coated with an active material. It is the negative electrode and its property decides the rate of charge and discharge of the battery. We try to maximize the surface area of the anode which affects the rate of flow of electric current through the external circuit, resulting in a higher rate of absorption or emission of lithium ions released from the cathode. Anode stores the lithium ions during the charge cycle of the battery. The image below shows the discharging and charging states of the battery showing the flow of electrons and ions during the process.



The most commonly used anodes in Li-ion cells are graphite and the oxide spinel Li4Ti5O12. Graphene is being investigated and is considered a better alternative that can increase the power density as well as the charge and discharge rate of the cell.

Electrolyte:

An electrolyte solution is an electrically neutral solution, both the electrodes are submerged in the electrolyte solution. Although the solution is neutral but when an electric potential is applied, the ions start flowing towards the electrode. During the charge cycle, the lithium ions move from cathode to anode, while in the discharge cycle the reverse happens. Electrolyte plays a major role in the movement of ions thus making the flow of current possible. The movement of anions and cations in opposite directions in the electrolyte causes the flow of current.

For a Li-ion cell, the electrolyte needs to be a lithium salt, hence the most commonly used electrolyte in a Li-Ion battery is LiPF6 dissolved in an organic solvent.

Separator:

The separator plays an important role in the functioning of the battery. The electrolyte acts as a medium between the electrodes while the separator is placed between the electrodes to isolate them from each other so that no electron flows through them while allowing the ions to flow between them. The separator forms a catalyst when covered with the electrolyte thus facilitating the movement of ions between anode and cathode while stopping the electrons. When excessive heat is applied, the pores of separator get clogged by the melting process, this property can be employed as a safety feature, making the separator act as a fuse, stopping the flow of current in case of overheating thus safeguarding the battery from fire.

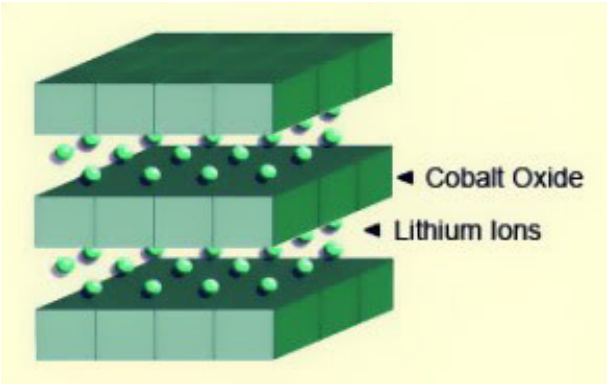
Most batteries for mobile phones and tablets which need to be kept lightweight and do not have a very rugged use have a single polyethylene separator while larger industrial batteries deploy tri-layered separator that acts like a fuse, protecting fires during extreme temperatures and on multi-cell configurations.

Types of Li-ion Battery

Li-ion batteries can be classified based on the combination of anode and cathodes used. There are six categories of lithium-ion battery readily available in the market, these are Lithium Cobalt Oxide (LCO), Lithium Manganese Oxide (LMO), Lithium Nickel Manganese Cobalt Oxide (NMO), Lithium Iron Phosphate (LFP), Lithium Nickel Cobalt Aluminum Oxide (NCA), and Lithium Titanate (LTO). Apart from the LTO battery, all other Li-ion battery has graphite as an anode. All the above Li-ion chemistries have different properties and we need to know their properties, their operating conditions and other parameters in order to select the best battery for our application. The properties of all the chemistries are given below.

1. LITHIUM COBALT OXIDE (LCO): Energy Dense but Low Thermal Stability

Lithium cobalt oxide battery have cobalt as the main active material in its cathode. It was invented in 1991 and has been extensively used because of its high energy density of 150-200 Wh/kg. Although this battery chemistry is energy dense, but other options are being investigated as the experts are claiming that the world could face a cobalt supply shortage soon. This is due to the surge in sales of electric vehicles where this battery chemistry is extensively used, leading to increase in cost over time.



Cobalt is a highly volatile metal, which limits the current handling capabilities of LCO battery due the risk of overheating. Furthermore, LCO batteries have lower thermal stability, that makes them sensitive to higher operating temperatures and overcharging. LCO batteries are extensively used in portable electronics such as phones, cameras, laptops and have a high demand in electric vehicles.

2. LITHIUM MANGANESE OXIDE (LMO): The Safest Li-ion Chemistry

Lithium manganese oxide batteries are also known as lithium-ion manganese batteries. It has $LiMn_2O_4$ as a cathode. The earliest commercially developed battery with this chemistry was produced in 1996. These batteries have low internal resistance and high temperature stability which makes them safer than other lithium-ion battery types. LMO batteries are capable of delivering current up to 20-30 Amps due to their low internal resistance, thus making fast charging and discharging possible.

The main disadvantage of this chemistry is its relatively low cycle life of 300-700 cycles. These batteries also have lower capacity. Because of these drawbacks limited research and advancement of this battery type are expected in the future. LMO batteries are extensively used in applications where high C-rates are required such as power tools. It also has applications in EVs and in medical applications.

3. LITHIUM IRON PHOSPHATE (LFP): Affordable, Safe, and Reliable

Lithium iron phosphate batteries use phosphate as active material in the cathode. These batteries are one of the most used chemistries in electric motorcycles, e-rikshaw as well as other applications that need a long lifecycle and significant safety. These batteries have a moderately high energy density of 90-160 Wh/kg. Similar to LMO, LFP chemistry have low internal resistance resulting in higher thermal stability. Unlike the LCO battery, these batteries are durable and have a long lifecycle with low self-discharge rates. LFP batteries have one of the best life cycles making them a very cost-effective option considering their long operations life. However, the nominal voltage of 3.2V of the li-phosphate battery means that it has less energy than other types of lithium batteries.

LFP batteries are used in industrial equipment and heavy machinery due to their high thermal stability and great life cycles. They are widely used in EVs, especially in e-bikes, e-rikshaw, and many cars because of their ability to withstand a lot of mechanical and thermal abuse.

4. LITHIUM NICKEL MANGANESE COBALT OXIDE (NMC): Expensive but High Performing Battery

Lithium Nickel Manganese Cobalt Oxide (NMC) Batteries uses a combination of nickel, manganese and cobalt as the active material for its cathode. The most commonly used ratio is 60 percent nickel mixed with 20 percent each of manganese and cobalt to form the alloy. Changing the ratio of these metals can alter the property and we can either attain a high specific energy density or a high specific power. These batteries are cheaper than other Li-ion batteries and have a very low self-heating rate and a nominal voltage of 3.7V. NMC batteries have energy density of 150-220 Wh/kg, which is higher than most other chemistries. This battery is commonly used to power medical equipment, power tools and is considered as one of the preferred battery chemistries for EVs.

5. LITHIUM NICKEL COBALT ALUMINUM OXIDE (LINICOALO2) NCA: High Energy with Long Life

Lithium Nickle Cobalt batteries, also known as NCA batteries have a combination of nickel, cobalt and aluminum as active material in its cathode. These batteries have a high life cycle and are one of the most energy-dense Li-ion chemistry with energy density as high as 260Wh/kg and a nominal voltage of 3.6V. But the main disadvantage of this battery is its lower thermal stability and high cost making them an unviable option for consumer electronics. They are a good option for EVs due to their energy density, the NCA batteries must be used in cars with extra safety measures to monitor their performance and other data to keep the drivers secure.

The NCA batteries are becoming increasingly important in electric power trains such as in Tesla and find application in grid storage due to their lifespan and energy density.

6. Lithium titanate LTO: Long life, fast charge using advanced Nanotechnology

Lithium titanate, also known as li-titanate are one of the newly developed Li-ion chemistries. They have advanced nanotechnology and replace the graphite used in the anode with lithium titanate as the active material. The large surface area of Li-titanate allows a larger quantity of electrons to enter and exit the anode faster, making a very high rate of charging and discharging possible without compromising on safety. The main drawback of this battery is that it suffers from is the low nominal voltage and low energy density of 2.4V and 50-80Wh/kg respectively. What makes this battery special is its ability to provide discharge rate exceeding 30 C for a short period of time. The use of advance nanotechnology makes it one of the safest chemistries available in today's time.

Currently, a lot of big manufacturers of electric vehicles and bikes such as Mitsubishi, Honda, etc., use li-titanate batteries, and there is potential for this type of battery to be used in electric buses for public transportation. LTO batteries have potential scope in aerospace, military and are used in battery energy storage systems for storing wind energy and solar energy and for creating smart grids. Their ability to sustain high discharge rates make them a preferred option for frequency control devices for grid applications.

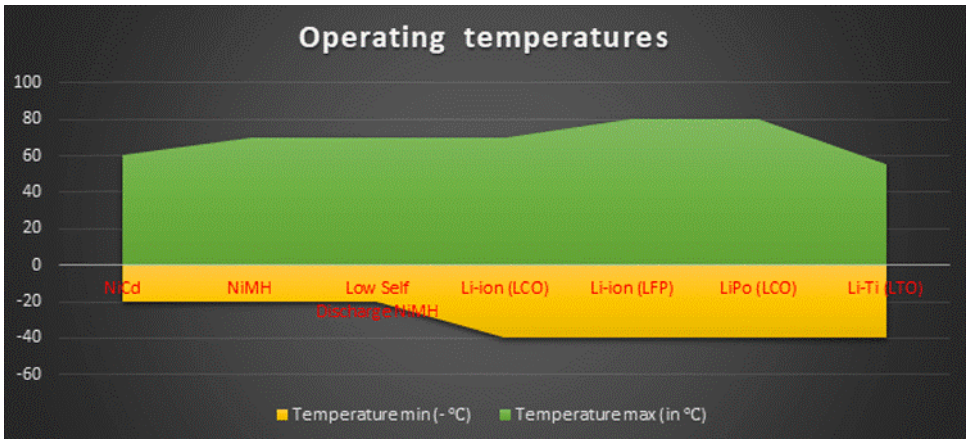
Battery Comparison

The battery can be compared on many different parameters such as nominal voltage, the weight of the battery, specific energy, etc. The chart given below compares data of different chemistry of Li-ion cell. For reference, we have also added NiMh, Ni-cd battery in the table below.

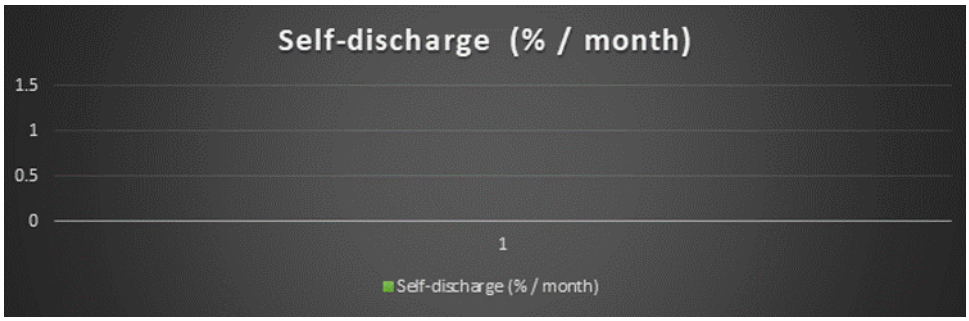
Battery Chemistry	Temp min (°c)	Temp max (°c)	Cell Voltage (volts)	Self-discharge (% / month)	Cycles Times (max)	Weight
NiCd	-20	60	1.2	20	800	Heavy
NiMH	-20	70	1.2	30	500	Middle
Low Self Discharge NiMH	-20	70	1.2	1	2000	Middle

Li-ion (LCO)	-40	70	3.6	10	1000	Light
Li-ion (LFP)	-40	80	3.2	5	12000	Light
LiPo (LCO)	-40	80	3.7	10	1000	Lightest
Li-Ti (LTO)	-40	55	2.4	5	20000	Light
LMO	-	85	3.7	-	700	Heavy

For better representation of the above the data, the graphs have been drawn. The first graph represents the operating temperatures of different battery chemistry while the second graph shows the self-discharge rate of different battery chemistry.



From the above graph, it is clear that all the Li-ion chemistries have a broader operating range than the Nickel based batteries.



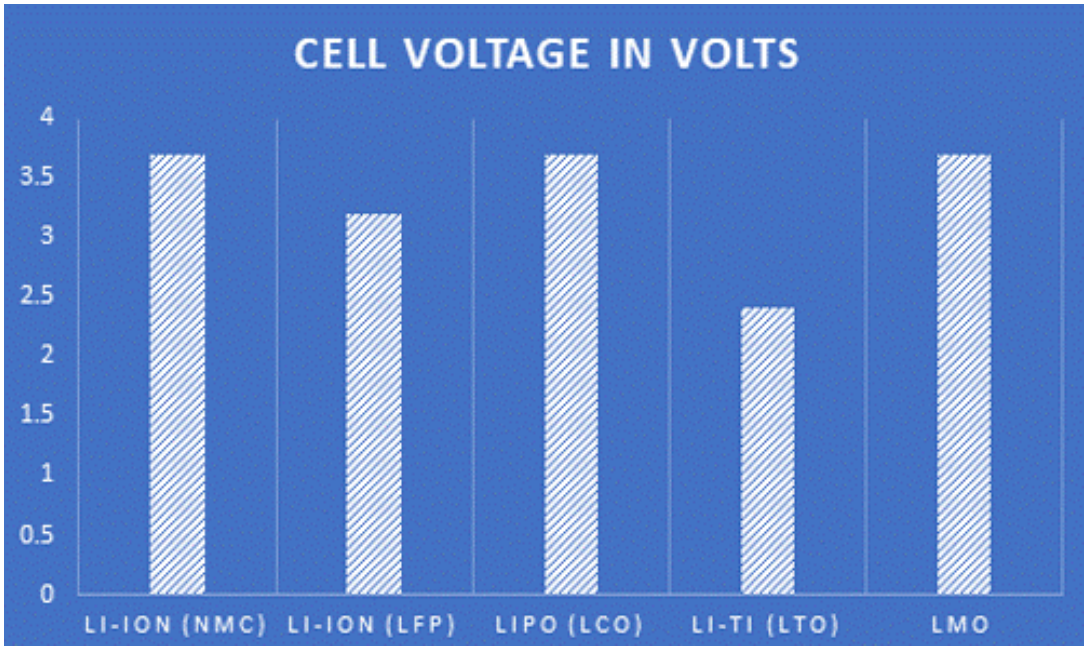
From the above graph showing the self-discharge rate, it is clear that most of the Li-ion cells have a very low self-discharge rate.

Comparison of Different Li-ion Chemistries

The property of Lithium-ion cell depends completely on the cell chemistry. All the chemistries have their own pros and cons which need to be considered while selecting a battery for a specific usage. The table listed below compares different Li-Ion chemistries.

	Lithium Titanate (Li_2TiO_3) — LTO	Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$) — NMC	Lithium Iron Phosphate($LiFePO_4$) — LFP	Lithium Nickel Cobalt Aluminum Oxide ($LiNiCoAlO_2$) — NCA	Lithium Cobalt Oxide($LiCoO_2$) — LCO
Voltages Nominal (Volt)	2.40V	3.70V	3.30V	3.70V	3.70V
Typical operating range (V/cell)	1.8V–2.85V	3.0V–4.2V	2.5V–3.65V	3.0 V–4.2V	3.0 V–4.2V
Specific energy (Wh/kg)	50–80Wh/kg	150–220Wh/kg	90–120Wh/kg	200-260Wh/kg	150–200Wh/kg.
Charge (C-rate)	1C typical; 5C maximum, charges to 2.85V	0.7–1C, charges to 4.20V	1C typical, charges to 3.65V	0.7C, charges to 4.20V, fast charging possible with some cells	0.7–1C, charges to 4.20V
Discharge (C-rate)	10C possible, 30C 5s pulse	1C, 2C possible on some cells	1C, 25C on some cells	1C	1C
Cycle life	3,000–7,000	1000–2000	5000-7000; up to 12000 possible in some cells	500	500–1000
Thermal runaway	200°C +	210°C (410°F)	270°C (518°F)	150°C (302°F)	150°C (302°F)
Cost (per kWh)	~$1,005	~$420 per	~$580	~$350	-
Application	Electric vehicles, UPS, etc	E-bikes, E-Rikshaw, industrial equipment, etc	E-bikes, E-Rikshaw, Battery Energy storage system for discoms, offices and homes	Medical devices, industrial equipment, electric vehicles	Smart watches, mobile phones, tablets, laptops, cameras

The graph shown below compares the nominal voltages of different Li-ion Chemistry.



From the above graph, we can say that the nominal voltage of NMC, LCO and LMO is higher than other chemistries while that of LTO is lowest. If we compare the data for energy density from the table, we find that the chemistry follows the same trend with LTO having the lowest energy density.
In terms of cycle life, LFP and LTO have the best cycle life while the NCA and LTO have a very low cycle life making them unfit for EVs. LFP, NMC and LTO have the best thermal runaway making them most suitable for operations in extreme temperature.

When considering the costs, LTO performs well in most parameters, but the cost is not justifiable for con sumer products and everyday portable equipment, whereas, NMC and LFP provides best of both worlds, they are competitively priced, while providing a decent performance and although NCA is cheaper than the other options but its poor thermal performance makes it dangerous for EVs and other operations where high temperature and mechanical stress is common, thus extra cost has to be considered for employing additional safety features to make it safe to use.

To sum up, it can be said that Li-ion batteries are the future of energy storage, the specification of cell depends on the internal composition, i.e. the material used for the electrodes, separator and the electrolyte. By changing the cathode, properties such as specific energy, charging rates, cycle life, nominal voltage, etc. can be controlled but every chemistry has their own pros and cons which needs to be considered while selecting the li-ion cell for a product.

In terms of cycle life, LFP and LTO have the best cycle life while the NCA and LTO have a very low cycle life making them unfit for EVs. LFP, NMC and LTO have the best thermal runaway making them most suitable for operations in extreme temperature. When considering the costs, LTO performs well in most parameters, but the cost is not justifiable for consumer products and everyday portable equipment, whereas, NMC and LFP provides best of both worlds, they are competitively priced, while providing a decent performance and although NCA is cheaper than the other options but its poor thermal performance makes it dangerous for EVs and other operations where high temperature and mechanical stress is common, thus extra cost has to

be considered for employing additional safety features to make it safe to use. A lot of research is going on in the field of battery and according to industry experts, the energy density of battery will increase with the cost expected to decline in the coming future.

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OVERCOMING LCD HMI CHALLENGES WITH SMART LCD DISPLAYS

HMIs are often used in applications ranging from rugged industrial controls to highly-sensitive medical devices. Most modern HMIs use touch-screen LCDs to allow users to view and interact with important data. While LCDs typically work exceptionally well in this area, there are some drawbacks to their use. Most notably, challenges lie in the time required for the design, coding, and testing of the display.

Smart LCDs, such as the one shown in Figure 1, attempt to meet these issues head-on.

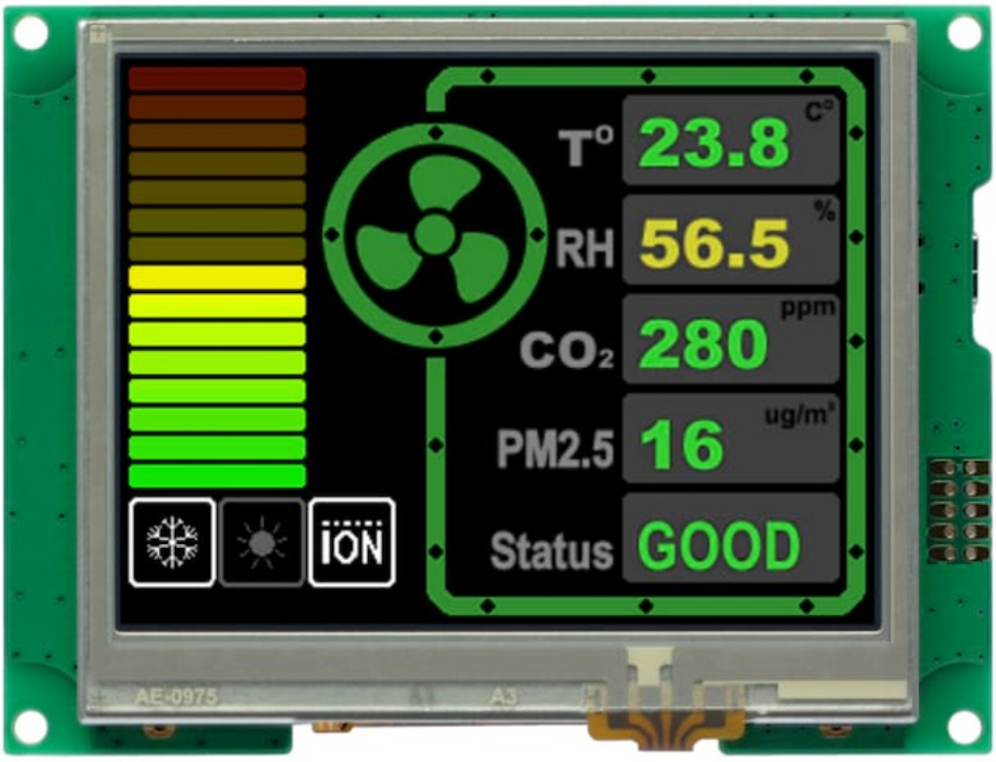

Figure 1. Example of a small 3.5-inch smart LCD display. Image used courtesy of Topway.

This article will aim to explain some of the challenges facing LCD touch-screen HMI designs, as well as how a designer might integrate them.

LCD Touch-screen HMI Development Challenges

Engineers responsible for the design and implementation of touch-screen LCDs for HMIs face several major hurdles. The first, perhaps most challenging and time-consuming problem is the code development and testing stage.

This stage in the development process can easily take months and may require extensive programming skills. The time required to develop and test code naturally extends development time and time-to-market. GUI design, display configuration, and touch-screen functionality can also require significant coding, adding to the already substantial time required for system development and testing.

Additionally, display circuits and touch-screen circuits must be included apart from the microcontroller unit (MCU), leading to a greater probability of failure as well as increased component count and overall product cost. This can also require additional wiring, wiring harnesses, and testing.

With all the requirements in mind, why would designers still want to develop touch-screen LCDs for HMIs? Generally speaking, a well-designed HMI allows a human to interact with a machine in the simplest, most intuitive way possible. Touch-screen interaction can be extremely intuitive for users, whether it involves tapping a button or dragging through a list of options.

Touch-screen GUIs make it more likely that end-users will interact correctly with the equipment, even when they may be in a hurry. In many cases, correct interaction not only means getting the most use out of a product but can do so in a safe manner. Additionally, many times those GUIs may require colorful graphics to ensure that the user's eyes are drawn to the most critical information.

For example, consider LCD HMIs for EV (electric vehicle) charging stations. Users are typically in a hurry and distracted by a myriad of things in their environment (e.g., the roar of nearby traffic, rain, or their electronic devices). Users need to be able to select the right options for their vehicle and interpret available information in a clear, concise manner. An example of such an LCD solution is shown in Figure 2.

Figure 2. LCD module for an EV charger. Image used courtesy of Topway.

In designs such as this, the need for such a solution outweighs issues associated with touch-screen LCDs.However, a question to consider is: what if there is a touch-screen LCD option for HMIs that can address every problem just discussed? The

solution: smart LCDs.

Integrating Smart LCDs Into Designs

A smart LCD is a TFT (thin-film transistor) LCD module with an embedded MCU, display engine, and touch controller. Smart LCDs could allow engineers to design and implement HMIs much more quickly than traditional LCDs. In addition, smart LCDs can be exceptionally well adapted for use with HMIs intended for IoT (Internet of Things) applications displaying real-time data. This is, in part, because the embedded MCU makes it possible to efficiently display real-time data rather than mere passive data.

Figure 3 contains a block diagram showing how a traditional TFT LCD module compares to a smart one in terms of components and encapsulation.

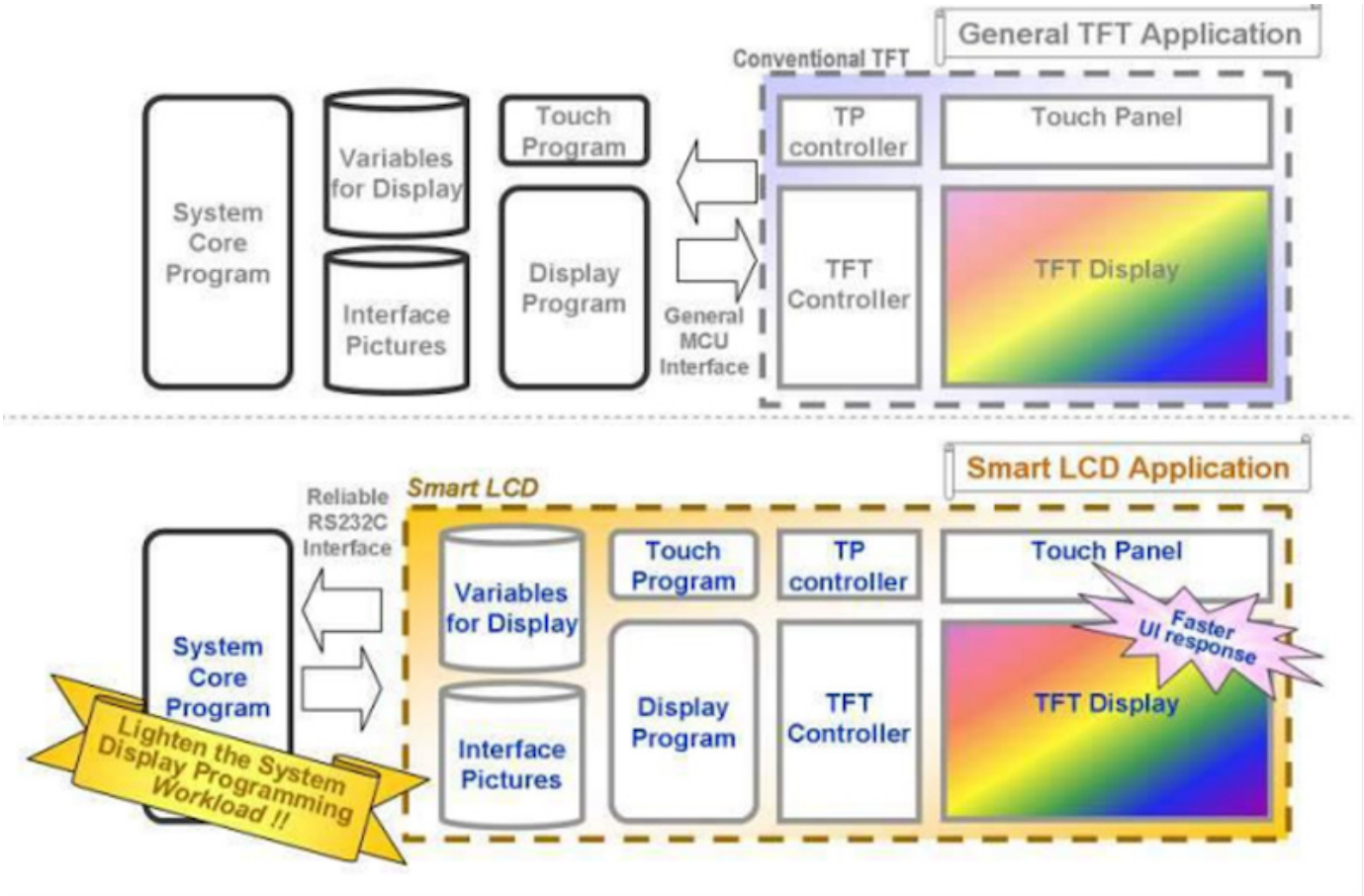

Figure 3. A traditional TFT LCD HMI compared to a smart TFT LCD. Image used courtesy of Topway.

There are several features of smart LCDs that can make them particularly useful. For example, the embedded display engine minimizes the workload on the MCU, enhancing the efficiency of its performance, and reducing the overall design cost.

While traditional LCDs require a display circuit, the smart LCD has one built-in, which means no display code needs to be written. Programming is done graphically, which can help eliminate the need for complex, time-consuming, manual code development, as shown in Figure 4.

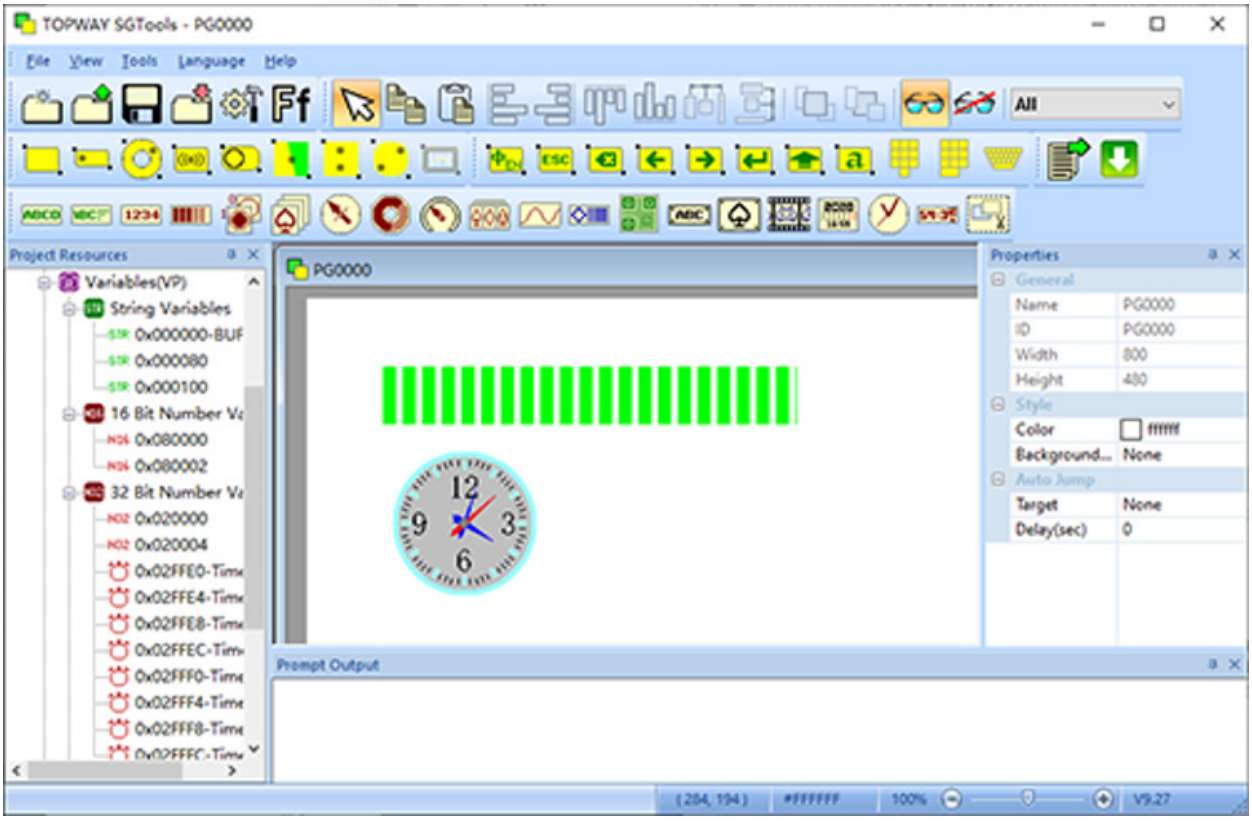

Figure 4. Creating a user interface using a smart LCD requires simple drag-and-drop tools and no coding. Image used courtesy of Topway.

Smart LCDs can utilize very high-level programming capabilities via script engines, such as Lua, which use simple serial level commands.

Since smart LCDs have the display engine and touch control embedded in the display module, the display and touch-screen logic are encapsulated.

Additional benefits of a smart LCD include:

- Stronger, more stable EMC (electromagnetic compatibility)
- No need for a support circuit or the code required for it to function
- Working prototypes are available in a much shorter time because of the drastically reduced code development and testing workload
- Reduced BOM (bill of materials) and component count because the MCU, display engine, and touch controller are all embedded

All in all, smart LCDs can often support everything from simple HMIs to complex ones (such as the one shown in Figure 5) without requiring time-intensive, error-prone development.

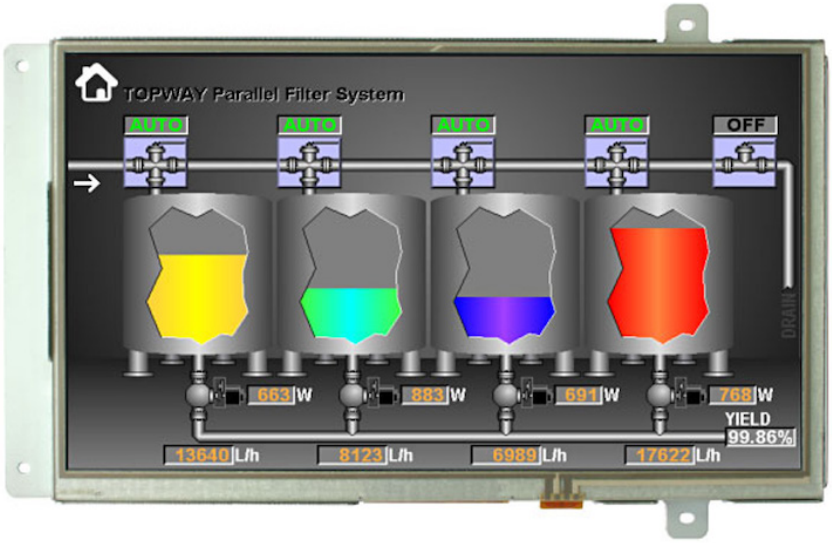

Figure 5. Smart LCDs can be used in a wide number of IoT applications such as the parallel filter system shown. Image used courtesy of Topway.

Smart LCD Solutions from Topway

Though we've covered some of the challenges for LCD touch-screen HMI design, as well as how a designer might integrate them, one potential solution is Topway's 7-inch Smart TFT capacitive touch LCD, shown in Figure 6.

Figure 6. The Topway 7-inch smart TFT capacitive touch LCD. Image used courtesy of Topway.

This solution aims to be suitable for IoT HMI applications, including:

- Instrumentation
- Medical electronics
- Industrial control
- Power equipment

As an example application use, one of Topway's customers was looking for an HMI for an EV charger (as mentioned earlier). In this case, it was installed on China State Grid's charging stations.

The requirements included:

- A real-time data display
- A high electromagnetic compatibility
- Backlight
- Low power consumption
- A wide operating temperature range
- A highly customized GUI

In addition to those requirements, the engineers developing the charging stations would prefer an HMI solution that does not require extensive coding and time-intensive testing. Such requirements do not apply just to EV charger HMIs, but to applications ranging from highly sensitive and complex chemical process controls to outdoor transportation kiosks. Aiming to check off all the requirements, especially to ease development strife, all Topway smart LCDs use the straightforward, 5-step procedure illustrated in Figure 7.

Figure 7. The 5-step process for implementing an HMI using a Topway smart LCD module. Image used courtesy of Topway.

The steps are:

1. Install Topway UI Editor
2. Import images and design the UI flow
3. Download to the smart LCD
4. Power on, display, and test
5. Connect to host and start viewing real-time data

In addition to all the requirements, the solution also provided:

- A 32-bit MCU
- A 1024 x 600 resolution on a 7-inch screen (active area of 154.21 mm x 85.92 mm)
- Support for remote user interface (UI) design updates through TCP/IP protocol and a built-in RJ45 LAN port
- LED backlight
- Operating temperature range of -20 C to 70 C.

Using the Five-step Process and Benefits for LCD HMI Development

The five-step process described above can be just as simple as it looks.

To develop a simple tachometer, for example, install Topway's SGTools software onto a computer, start a new project and add a static background image and static text (if desired). Next, drag and drop one of the tachometer elements and configure its basic properties, which include direction, colors, and min/max values.

Next, configure VP Resource, which is the type of VP to hold the content and is VP_N16 by default, and the VP Address, which is the VP that holds the value.

Then compile the project and download it to the smart LCD via a mini USB connecting the computer and the LCD. Once the download is complete, remove the mini USB cable, and power on the display. From there, a few simple codes will connect the tachometer to the correct data.

Smart LCDs like the ones from Topway can be an easy, potential solution with no complex coding but all the benefits of using a touch-control LCD HMI with real-time data.

The elimination of lengthy design, coding, and testing mean a much shorter product development time and a reduced time to market while still supporting complex HMIs that may include a number of interactive

control and data display elements. In addition, the number of components is much smaller leading to a lower product cost and less likelihood of failure.

Topway aims to understand the needs of engineers designing modern touch-screen LCDs, especially when those designs involve HMIs for IoT-enabled applications. See its selections here to learn more about its line of smart LCDs.

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FACULTY'S ARTICLES

FINDING SOLUTIONS FOR REAL-TIME EMBEDDED SOFTWARE DEVELOPMENT

Embedded processors have grown into complex and powerful devices that can often fulfill various requirements in a small physical package. As applications grow ever more complex, engineers must keep pace to manage the resulting increase in software complexity. In industrial applications, this software often runs for many years (if not decades), and managing embedded applications over their entire lifecycle is no trivial task.

In practice, a few overarching issues affect all non-trivial software projects, regardless of whether they rely on a RTOS or not. Examples of such problems include managing a build system over the entire lifecycle of an application, portability considerations, logging, and a shell mechanism. Below in Figure 1, you can see an example RTOS with customizable component sets.

Figure 1. A customizable component set within an example RTOS. Image used courtesy of NXP

This article introduces common problems as well as tasks for an RTOS. It then analyzes the need for standardization and reusability across systems for embedded software development before examining the role of Zephyr OS in an example application.

Time Consuming RTOS Challenges

Nearly every non-trivial software project requires a reliable build system, regardless of whether the project contains a real-time component or not. Maintaining such a build system over the entire lifecycle of an application, which can span multiple years, is not a simple task. Seemingly minor updates and changes in included components and external libraries can quickly lead to time-consuming error hunts that occupy a developer's time.

Software and Module Updates

Without a repository management tool, developers not only have to check for updates of the main RTOS core, but they also have to hunt down every change in every single external module used in their projects. However, it's essential to keep in mind that some modules depend on (or are based on) external libraries and modules, which the developers then have to track as well. Missing updates in these sub-modules can potentially break components built on top of the modules, leading to time-consuming error searches. Managing these chains of dependencies is no trivial task, and a repository or dependency management tool saves engineers lots of time they can instead spend focusing on implementing their embedded applications.

Cross-platform Porting

Porting a project from one device to another can quickly become a complicated and lengthy procedure. Even if engineers decide to employ different devices from the same manufacturer, the process might involve many time-consuming re-configuration tasks. Some fixes and implementations might work on one system while they don't function as intended when using other hardware.
The cause for such problems can be:

- Different memory layouts
- Changes in hardware addresses
- Differing hardware features
- Different driver interfaces

Take, as an example, a program that writes values to flash memory in a system. In their original design, engineers employed a microcontroller unit (MCU) that contained on-chip flash memory and a flash controller. However, due to supply shortages, the design team switched the design to a different MCU without built-in flash memory and an external flash memory module. As the software contains hardware-specific code for accessing the on-chip flash memory, the team can't easily port the application to the new MCU platform without redesigning significant parts of the codebase.

his problem can quickly lead to multiple similar code bases for different devices, which result in more severe problems further down the line—for example, when implementing bug fixes that affect all codebases. Library organization and configuration management further increase the complexity of such re-configuration tasks.

Status and Error Logging

Typically, more complex projects require some logging mechanism to output debug and status messages or a shell that lets developers and external systems interact with the implemented software. However, these facilities are not always part of RTOS, and developers have to implement them or port a previously implemented solution to their current project. Custom implementations must also ensure thread safety and, therefore, must be evaluated and tested extensively before including them in the production version of the software.

Common RTOS Solutions

In light of the problems and tasks discussed above, many conventional RTOS' offer a real-time scheduler, synchronization support, and memory management features. Below, we provide an examination of several popular options (FreeRTOS, Azure RTOS, and Zephyr OS) and their potential benefits and drawbacks.

FreeRTOS

FreeRTOS started as a simple real-time kernel offering threads, synchronization, and memory allocation mechanisms. The lightweight nature of the project made it appealing for various embedded applications. As of this article's publication, the project is maintained by Amazon. The developers focus on adding additional cloud service integrations, such as support for the Amazon IoT core and other AWS services. The MIT license ensures that FreeRTOS stays free.

Additionally, the lightweight core scheduler is easy to integrate into projects, and the OS is still among the most popular RTOS' today. However, unlike ThreadX, FreeRTOS is not designed to be used with safety-critical systems. For such systems, engineers will have to fall back on using a commercially licensed product called SafeRTOS.

Azure RTOS

Microsoft Azure RTOS, formerly known as ThreadX, is an alternative to FreeRTOS. Overall, Azure RTOS grants better hard real-time capabilities than FreeRTOS, and it also conforms to various safety-relevant standards. However, there are a few overarching problems that neither of these options manages to solve efficiently.

One problem is how both FreeRTOS and Azure OS have been acquired by large companies that shape their futures. Since Amazon and Microsoft offer proprietary cloud services, they will likely make it easy for developers to connect to their specific cloud services. However, the companies could try to make integrating a different cloud service more cumbersome for developers.

Zephyr OS

In contrast, Zephyr OS is a relatively new project in the RTOS segment that aims to solve the problem mentioned above. It introduces standardized parts that developers can utilize in several projects across various supported platforms with minimal to no reconfiguration effort. Zephyr OS is a community-governed, open-source project that offers vendor-independent solutions that engineers can use without paying licensing fees. Due to this vendor-independent and open-source nature of the project, it's unlikely that a single company dramatically determines how well Zephyr OS integrates with other products and services. Figure 2 shows a block diagram for the Zephyr OS.

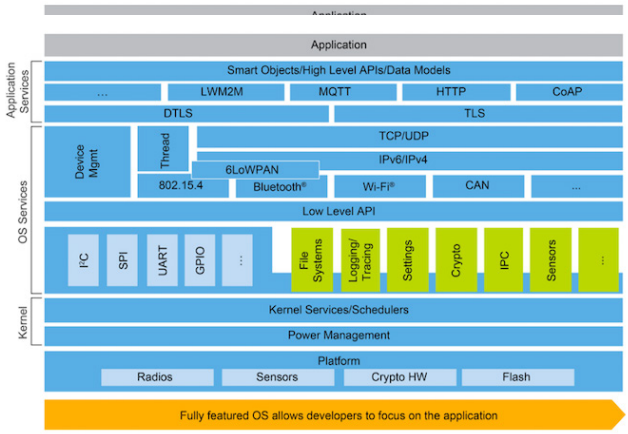


Figure 2. Block diagram of Zephyr OS structure. Image used courtesy of NXP

The publicly available source code of Zephyr OS and the extensive online documentation also ensure that embedded engineers can learn all the details about Zephyr they need to make critical decisions without reverse engineering any source files. In addition, open-source projects governed by many developers often have better security implementations compared to entirely closed-source solutions. Furthermore, practically any developer and company can add support for new architectures and hardware.

Example Solution—the Zephyr Project

The Zephyr project (Figure 3) features multiple, discrete blocks that work to streamline the build process and link disparate libraries through standardized components.

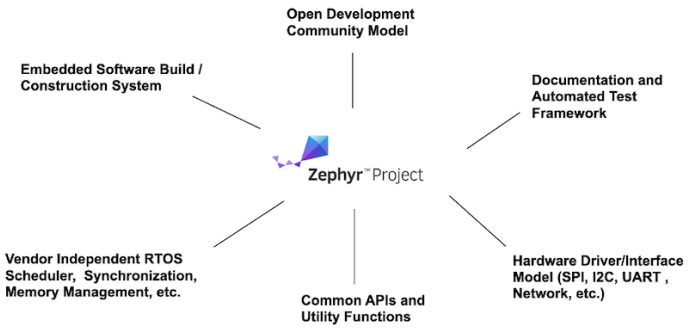


Figure 3. The main features of the Zephyr project. Image used courtesy of NXP.

In general, the Zephyr build system offers engineers the freedom to choose how they want to implement specific options and which built-in facilities they'd like to use. While the SDK includes many advantageous features, most of them are entirely optional. Engineers are free to utilize them in their projects or implement features how they've always done it.

The built-in peripheral and driver interface is another example of this approach. A standardized application programming interface (API) allows engineers to re-use lots of code for standard communication options such as I2C and serial peripheral interface (SPI). A universal asynchronous receiver-transmitter (UART) driver ensures that the built-in logging facility works right out of the box.

Zephyr Package Manager

Zephyr's built-in package manager—called West—pulls external packages from public or private repositories and kicks off the entire build process of an application. It is also responsible for flashing the MCU and can further generate a bill of materials (BOM).

Additionally, Zephyr keeps code that is not part of the Zephyr core in separate external repositories. These external repositories include reusable IoT application building blocks such as:

- Vendor HALs
- Filesystem implementations
- Public libraries (like OpenAMP and OpenThread)

Additionally, West can also manage other external libraries and code held in private repositories. These external components and third-party libraries have their own release schedule and CI/CD tool usage, completely independent of Zephyr. This meta-tool within Zephyr ensures that developers don't have to think about how they include external libraries in their projects. In addition, the team can focus on building their embedded application rather than tracking changes and dependencies across all external third-party and official software modules that were added to a Zephyr project. Under the hood, West uses CMake for managing the build process.

Borrowing from Linux

The Zephyr SDK borrows a few concepts from Linux, two of which are Kconfig and device trees. Within Zephyr, Kconfig offers a simple way of linking libraries to a project without exactly having to know which source files and build macros to use. The Zephyr SDK includes a simple implementation of Linux device trees, which allows developers to document what hardware is present in the system. However, in contrast to dynamic device trees (Figure 4) in Linux, Zephyr uses them more like a data structure that describes the hardware at compile time.

Built for mimxrt1060_evk

```
chosen {
   zephyr,flash-controller = &flexspi;
   zephyr,flash = &is25wp064;
};
flexspi: spi@402a8000 {
   compatible = "nxp,imx-flexspi";
   label = "FLEXSPI";
   status = "okay";
   is25wp064: is25wp064@0 {
      compatible = "nxp,imx-flexspi-nor";
      size = < 0x4000000 >;
      label = "IS25WP064";
      status = "okay";
      erase-block-size = < 0x1000 >;
      write-block-size = < 0x1 >;
      partitions {
          compatible = "fixed-partitions";
          #address-cells = < 0x1 >;
          #size-cells = < 0x1 >;
          storage_partition: partition@630000 {
             label = "storage";
             reg = < 0x630000 0x1d0000 >;
          };
      };
   };
};
```

Built for frdm_k64f

```
chosen {
   zephyr,flash-controller = &ftfe;
   zephyr,flash = &flash0;
};
ftfe: flash-controller@40020000 {
   compatible = "nxp,kinetis-ftfe";
   label = "FLASH_CTRL";

   flash0: flash@0 {
      compatible = "soc-nv-flash";
      label = "MCUX_FLASH";
      reg = < 0x0 0x100000 >;

      erase-block-size = < 0x1000 >;
      write-block-size = < 0x8 >;
      partitions {
         compatible = "fixed-partitions";
         #address-cells = < 0x1 >;
         #size-cells = < 0x1 >;
         storage_partition: partition@1e000 {
            label = "storage";
            reg = < 0x1e000 0x2000 >;
         };
      };
   };
};
```

Figure 4. This image compares the device trees for the two evaluation boards used in this example. The highlighted segments show the differences between the two files. The label is marked because it is required by littlefs, the filesystem used in this example. Image used courtesy of NXP

This description remains static and doesn't change during runtime.

Example Use Cases for Zephyr

Let's take a closer look at two example use cases—each utilizing an MCU's GPIO to control the states of some pins—to illustrate how these features come together from the vantage point of designers actually working within this space.

Porting Across MCU Platforms

In this first example, an original board that used an LPC55S69 MCU offered a sufficient number of usable GPIO pins for an industrial I/O panel application. A later iteration of the design, however, employed an S32K118 MCU (from another hardware family, with a comparable number of usable I/O pins).

This new design comprised more external components and the MCU didn't offer enough accessible GPIO pins. Therefore, the engineers added an SPI-to-GPIO expander to compensate for the missing channels, and they needed to share as much source code between the two projects as possible.

Using Zephyr's already-included driver (which allowed the SPI-to-GPIO converter to appear to the

system as regular MCU GPIO pins), the developers didn't have to change the source code. Instead, they only had to update the device tree for the newer board design. This lets the designers avoid needing multiple codebases, complicated adaptations to the source code, and a lengthy regression-testing and porting process. This example further highlights that engineers should rely on tried and tested simple implementations rather than quick fixes and hacks to maintain an application's reliability and security.

Porting Across Different Packages and Pinouts

Even though Zephyr is very board-specific, developers don't need to write a new device tree source file for each custom board of a family. In other words, developers can utilize an evaluation kit for testing an MCU they want to use in a product, such as the LPC55S69. For the prototype, they can use the LPC55S69-EVK and the DST supplied by the manufacturer—in this case, NXP. This can be shown in Figure 5.

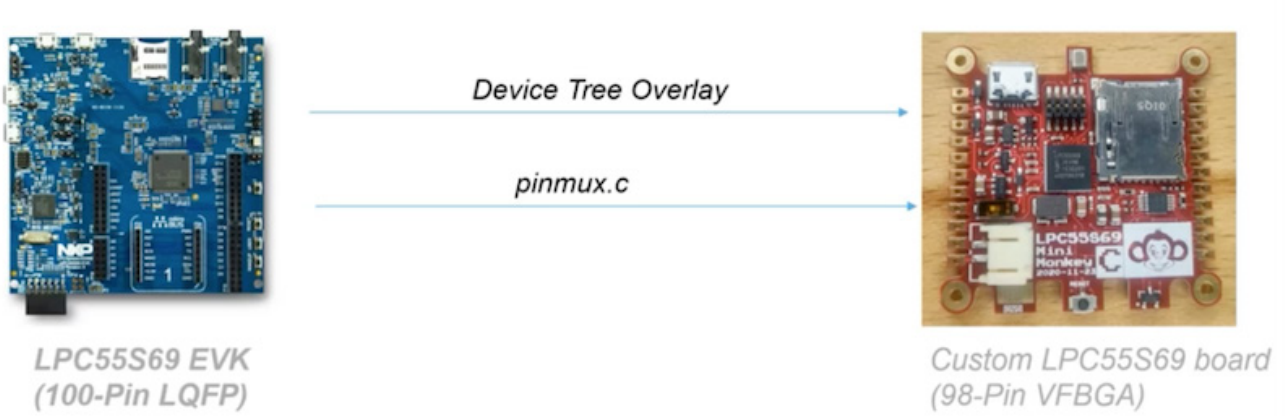


Figure 5. Engineers only need to make minor adjustments to the Zephyr device tree structure and the pinmux.c file to port an application from an EVK to a custom board that uses the same chip in a different package. Image used courtesy of NXP.

Once the developers verify that the code works on the evaluation kit, they only need to create a custom device tree overlay (DTO) for their specific custom board. The overlay file describes the particular hardware of the custom board so that the Zephyr build system can interface it.

Pushing RTOS' to the Next Level

This article has examined several overarching problems endemic to the use of conventional embedded RTOS'. First, managing a software product over its entire lifecycle is no trivial task. The problems begin with maintaining and updating third-party and official external libraries. Developers often have to keep track of updates made to those libraries. Updating those referenced libraries always comes at a risk, as doing so potentially leads to invalid or broken dependencies and version incompatibilities.

Security concerns and potential vulnerabilities plague practically all larger software systems, and real-time operating systems are no exception. Even established protocols and products can get compromised even after many years of reliable operation. However, closed-source and proprietary software products are at greater

risk, as fewer developers can inspect the code and test possible security shortcomings. Open-source systems like Zephyr provide an accessible way for developers to ensure standardization and reusability in their designs from the ground up.

PROF. PRIYANKA TRIPATHI
ASSISTANT PROFESSOR-EC

PCB LAYOUT CHALLENGES—IMPROVE YOUR SWITCHED-MODE POWER SUPPLY DESIGNS

Switched-mode power supplies (SMPS) appear simple to route on your PCB, but are they? This article identifies two noise sources and simple fixes to improve your EMC performance. Chip manufacturers often try to make it incredibly simple for designers and hobbyists to implement most SMPS using modern web applications or even power design software. Backing up the software are application notes suggesting the correct PCB layout for their specific ICs.

Although the design software today is typically excellent, the problem is that most app notes can be wrong, at least partially so. In fact, several industry experts note they should be assumed wrong until proven right.

A Hidden PCB Layout Threat—PCB Coupling

EMC principles relating to SMPS usually require that a designer pay close attention to two coupling factors, shown in Figure 1, in the layout of SMPS:

- The voltage switching node, which has a high dv/dt
- The "hot current loop," which contains the highest di/dt in the subsystem

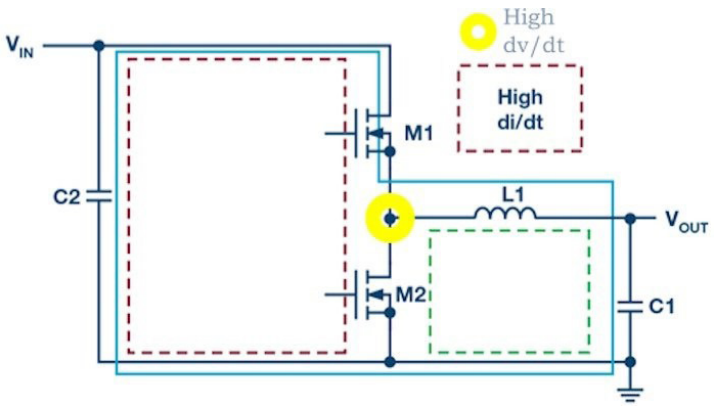


Figure 1. A schematic showing buck converter di/dt & dv/dt locations. Image (modified) used courtesy

of Analog Devices

The mechanisms and risks at play here are capacitive (dv/dt) and inductive (di/dt) coupling of unwanted energy to other parts of the system, or worse, out of the system in the form of radiated and conducted emissions.

A PCB Design Post-production Review

Diving into the project, we are going to examine the PCB layout of an LM22678 5A converter (Figure 2) with a Vin of 12 V (not shown) and a Vout of 5 V. This is a non-synchronous buck converter using a B130L-13-F Schottky diode for its low-side switching element (and yes, before you check—the system draws less than the 1 A rating of the diode!).

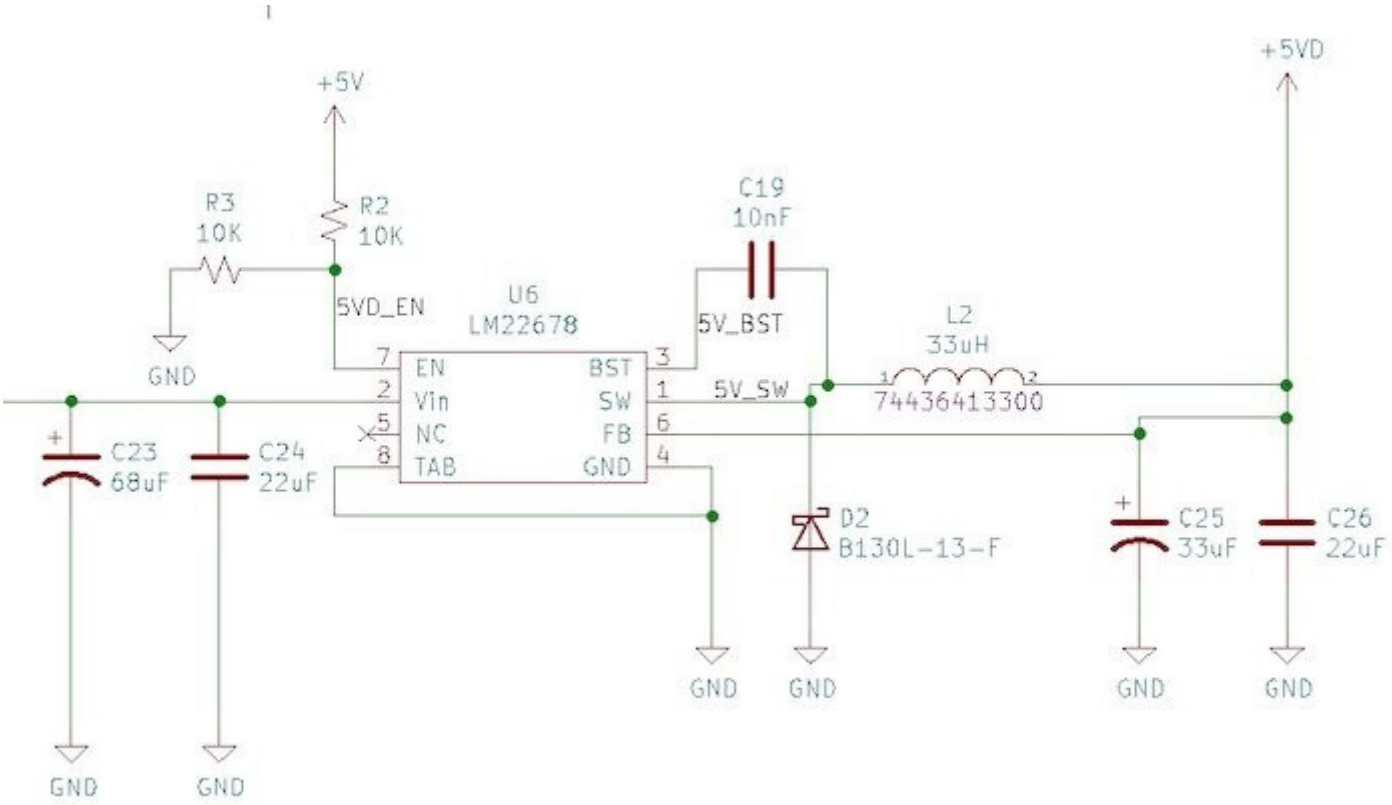


Figure 2. The schematic for a non-synchronous LM22678 buck converter 12 V to 5 V.

Minimizing capacitive and inductive coupling is typically not complicated but it is easy to overlook, leading to failing emissions testing and market delays. Below, in Figure 3, we see the layout of a TO-263 package for the non-synchronous buck regulator with the voltage node (red outline) and hot current loop (yellow outline) identified.

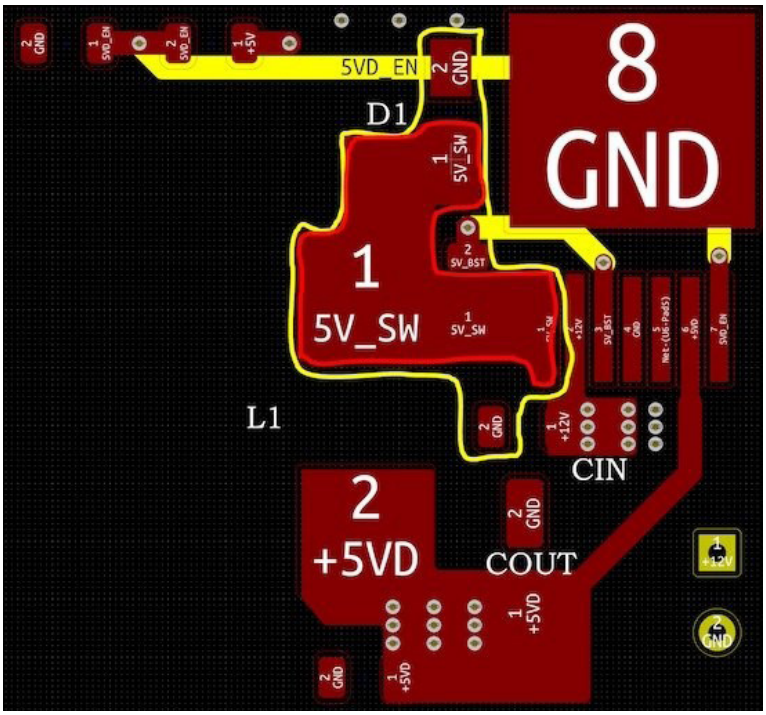


Figure 3. Non-synchronous buck regulator design with low-side power diode.

For clarity, the copper fills on the board have been hidden. Overall, there are three glaring issues with this design:

1. The high di/dt loop is far larger than it needed to be

2. No vias connect the GND nodes of CIN or COUT (they were ground pour covered)

3. The switching node could be smaller

The net effect of these design choices means that the current loops are not well contained, and the current does not have a well-defined path back to the source due to a lack of vias between the planes.

For EMC—(Electrical) Silence Is Golden

Applying the principles gleaned from Dr. Hubing's discussion, the improved layout can be seen below in Figure 4. It features an optimized voltage node, a smaller hot loop and via access to the layer 2 reference plane for each passive component. Additionally, the primary COUT capacitor was also rotated 90 degrees relative to the original design reducing the risk of noise on the output rail.

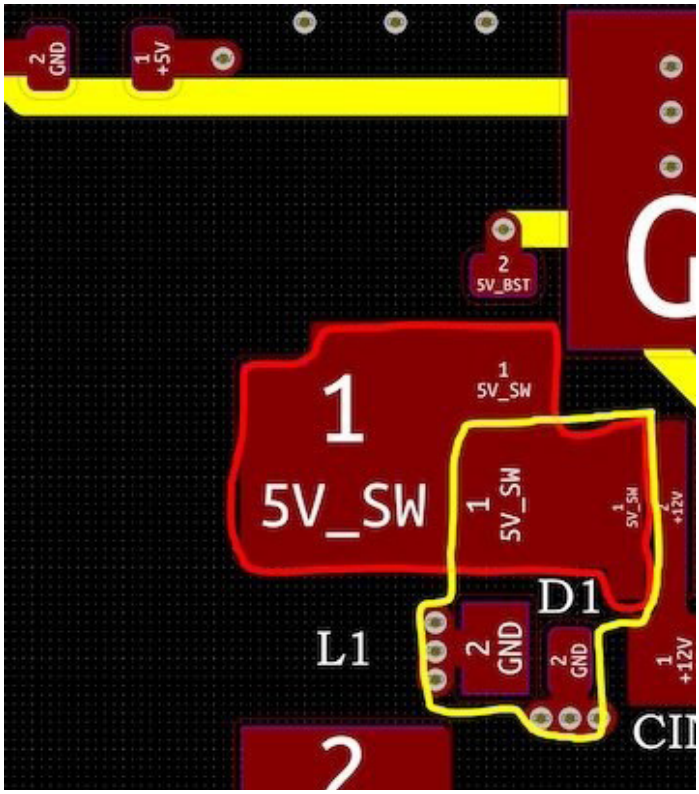


Figure 4. The improved layout takes the coupling mechanisms into account.

By moving the low-side diode inline between the switch pin and the inductor, we are better constraining the potential crosstalk noise generated by the high dv/dt coupling effects. Further, by reducing the hot loop geometry the effects of high di/dt magnetic field coupling are decreased.

Though these changes are small, they require no additional board space or shuffling of other subsystems. However, the system compliance was undoubtedly enhanced by reducing the current loop by approximately 50% and optimizing the voltage node.

When you are designing commercial products to comply with CISPR EMC standards, every dBµV counts, and small changes at the design stage might mean the difference between a profitable launch or a missed market window.

Key Takeaways

- Understand where the current loops flow in your switched-mode power supply
- Keep node and loop geometry small to mitigate unwanted coupling effects
- Keep CIN away from or COUT to help isolate current loop induced fields, and prevent dv/dt crosstalk
- Tie pads to vias, not just ground fill copper to assist in constraining the return current

PROF. SURYA BAZAL
ASSISTANT PROFESSOR-EC

HOW WILL 5G SUPPORT AND BENEFIT INDIA'S UPCOMING TECHNOLOGIES AND APPLICATIONS?

A year back, the government of India has taken an initiative to craft the country into a five trillion dollar economy towards the end of 2025, and one of the key requirements to turn this goal into a reality is revolutionizing the nation's digital infrastructure. The country has already dug deep into enhancing the digital infrastructure, but experts claim that 5G services will be the key to a successful digital India. The question still remains when will 5G be available in the country in a full-fledged way. To answer this question, the Department of Telecommunications (DoT) recently stated that it will be available in mid or Q4 of 2022. The department also proclaimed that at first the services will be available in 13 cities and then the rest of the country will enjoy the benefits of this service. Ahmedabad, Bengaluru, Chandigarh, Gandhinagar, Gurugram, Hyderabad, Jamnagar, Kolkata, Chennai, Lucknow, Pune, Delhi, and Mumbai are the first 13 cities to enjoy 5G.

5G has ultra-low latency through which it will offer speedier and seamless communication all over the world. This next-generation cellular technology will spearhead and empower modern cutting-edge technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Augmented Reality (AR), Virtual Reality (VR), and machine-to-machine communications. It will ultimately support a huge range of modern applications and use cases such as self-driving, facial recognition systems, connected devices, chatbots, and many more. In an interaction with the media, Nitin Bansal, managing director of Ericsson India said 5G will boost the economic growth in India and it will assist service providers in monitoring and managing the increasing data requirements of consumers in an efficient manner. The early use-cases for 5G in the country are speculated to be fixed wireless access (FWA) and enhanced mobile broadband (eMBB) that would aid in solving the troubles of limited fixed broadband services and perk up the data experience while on the go.

Now, the question is why India needs 5G badly in 2022. Satyajit Sinha, Senior Analyst at IoT Analytics told CircuitDigest, "The mobile operators will not only be assisted by 5G in monitoring the escalating data requirements of consumers, but also open the gates of revenues for them. 5G is already perking-up various industries in the world via commencing the fourth industrial revolution and by improving the network experience for several businesses and end consumers. In fact, 5G is speculated to spearhead the digital transformation of several sectors like education, energy and utilities, automotive, healthcare, manufacturing, and many more. Towards the end of 2030, the anticipated worth of 5G-enabled digitalization revenues in the country will reach around USD 17 billion."

How 5G will Lead India's Digital Transformation by 2025

People in the remote corners of the country enjoyed the benefits of 4G in a better way, but at the same time, we cannot overlook the imperativeness of broadband connectivity for the financial and social enhancement of the nation. The lockdowns have underlined the significance of connectivity in every aspect of our life starting from introducing work from home, the commencement of online trade on a large scale, online education and most importantly, connecting people. The digital India initiative that centers on empowerment depends massively on connectivity and the mobile networks in the country continue to offer its services on that promise.

According to telecom experts, 5G is not only about some giga-bit data speeds. In the beginning, the fuss was about the speed of the 5G deployments, but it is going to transform our life the way we live and play, and work. The fundamental shift from 4G to 5G would be multi-dimensional and the immensity is much bigger than the shift from 3G to 4G. 5G will not only offer a wide range of new-fangled spectrum to be put to use, but it will also become more effective than 4G in the spectrum already in utilization. It can accumulate more data than 4G for the same volume of spectrum.

5G will fetch a huge transformational shift in the teaching domain with remote learning coupled with teaching in the classroom to intelligently escalate the educational efficacies. In India, where 70 percent of people live in rural areas it becomes too difficult to provide top-notch education to everyone manually. Hence, 5G backed by ultra-low latency and higher speed will provide proper education and cater to a wider population. Then, when it comes to smart cities and smart homes, devices furnished with sensors communicating to each other will turn into key equipment. For homes specifically, people might witness cutting-edge AI backed personalization, automated grocery lists, tracking electronic devices, and automated deployment of everyday routines. In terms of smart cities, 5G has the potential to offer smart metering systems and smart electricity grids, safety mechanisms, waste disposal systems, and smart traffic management.

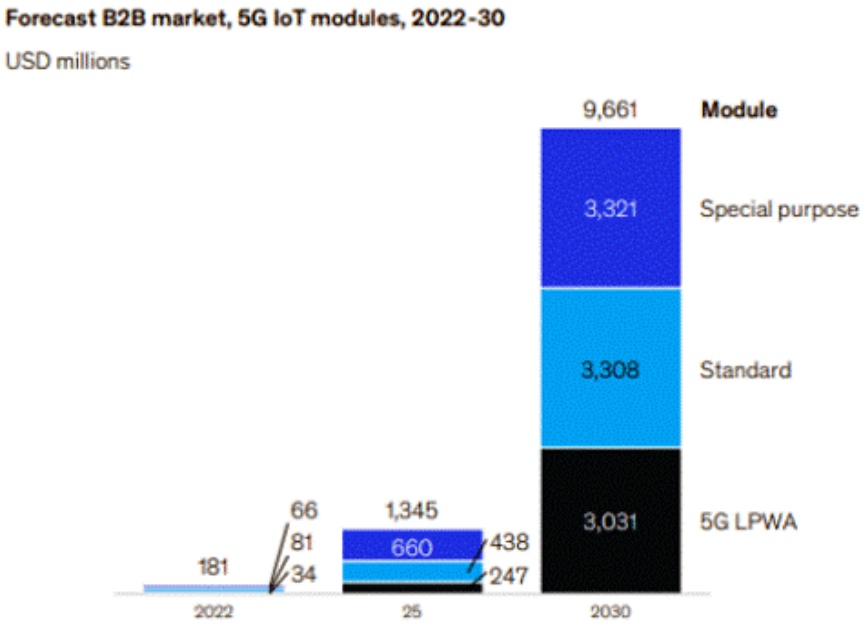
Highlighting the importance of 5G in India's digital transformation, Lt. Gen Dr. S.P Kochhar, Director General, Cellular Operators Association of India (COAI) said, "With the Prime Minister's inauguration of the 5G testbeds, the industry is on the pathway towards indigenization of 5G and it opens up opportunities for various other new-age technologies such as big data analytics, artificial intelligence (AI), augmented reality (AR) and virtual reality (VR), etc. which will drive major innovations across industries – Manufacturing, Supply Chain, Healthcare, Transportation and bring us closer towards our vision i.e. Digital India. A couple of impediments like cutting-edge infrastructure and Right of Way (RoW) policies being discussed thoroughly among the regulatory bodies and the unveiling of Gati Shakti Sanchar Portal is yet another promising move for the Indian telecom industry. Industry associations like COAI are working closely with the regulatory bodies and service providers to navigate through the challenges and further amplify the initiatives launched by the Government of India."

COAI also added that 5G network rollout is expected to add $450 billion to the Indian economy, increasing the pace of development and creating jobs. Prime Minister Narendra Modi recently said that 5G technology will bring positive change in the governance of the country, ease of living, and ease of doing business, especially newer opportunities for the B2B businesses.

Current Role of 5G in Averting Security Risks for IoT Devices

In the coming few years, the volume of IoT connections is expected to augment all over the world, which is about 25.2 billion towards the end of 2025, predicts GSMA Intelligence unit. The report also highlighted that over 3.1 billion out of the 25.2 billion would employ cellular technologies comprising low power wide area Mobile IoT networks. These days, a lot IoT backed devices utilizes wireless technology that comprises of short-range technologies, mostly utilizing unlicensed spectrum such as ZigBee, WiFi, and Z-Wave, and also and wide area cellular technologies, using licensed spectrum, such as LTE, 5G, and GSM. According to experts, cellular technologies that operate under a licensed spectrum offer a huge number of advantages for devices powered by IoT. These are mostly service enablement, sophisticated provisioning, and also device management. Apart from that cellular networks provide a huge international coverage and accurate reliability, performance, and security, which are required by the most promising and in demand IoT applications.

Now, talking from a security perspective, there could be 1.8 billion 5G connections by the end of 2025 as per the GSM association. Back in 2020, the 5G IoT market reached a value of USD 1.5 billion and is speculated to stand USD 40 billion by the end of 2026, at a CAGR of 72.9 percent over the time slot between 2021-2026. When 5G is amalgamated with IoT, it escalates the operational performance of several devices, but at the same time, high-end risks emerge. According to Satyajit Sinha, there is huge difference between deployment of IoT and deployment of 5G, which is regarding the standards that are available in either of these technologies.



Forecast B2B market, 5G IoT modules, 2022-2030
(Source: McKinsey analysis)

Basically, the IoT powered devices are still highly unregulated and then follow no generic standards. An IoT device is crafted out of hardware and sensors that further connect a layer of software and the sensors. The software manages the hardware and sensor data and also does the computing. Apart from that, there is a communication interface available that permits connection to the 5G network. Now, crafting a basic security architecture is highly intricate as there are several ways to design, build, and utilize an IoT product.

The current risk assessments and methods are not perfectly designed to get to know about the IoT-based risks in a comprehensible manner. The devices will be on all the time and will be connected to the 5G network and ubiquitous. For instance, if you carefully look at smart home implementation, if there is a voice-enabled device, which is connected to an IoT-powered lock on the door, the person opens the door with his or her voice command. It is not fully secured because a thief who came to know the person has left the home, can come to the door and speak with the same voice command and can open the door. The point is there is absence of authentication at the IoT device. Now, another point to be noted is that 5G will still suffer from the 4G weakness, claims experts. Now, it is not possible to unleash a comprehensive 5G network all at once and in fact, in fewer places 5G is moderately deployed side by side a 4G software components and hardware for a certain time slot. Hence, to have a sturdy IoT security platform or a framework, it requires a multi-layered approach.

Conclusion

5G, after a constant transformation in the last two years, has grown from an emerging idea into a pervasive and important technology for mobile devices. The features of 5G that includes ultra-high density, ultra-high-speed, and ultra-low latency will be inserted into AI via wireless. The AI actions can be completed rapidly through 5G on the terminal side and it also perk-up personalized services, boost customer experience and decrease latency. In fact, 5G will also be benefited from the AI-enabled processing ability.

Highlighting the advantages, Neil Shah, Research Vice President at Counterpoint Research said, "The applications that are based on AI can respond in the accurate time to the data generated by the 5G networks, thereby offering new-fangled potentials for automation. Removing the conventional wireless algorithms with the help of proper machine learning, AI will be able to significantly decrease the price of manpower and enhance the total performance. It will also offer safety to the people's everyday life, encouraging digital transformation, modernizing several commercial and industrial activities, and unleashing endless top-notch products and services."

DR. NEETA NATHANI
HoD-EC

LIST OF PROFESSIONAL ACTIVITIES CONDUCTED IN THE SESSION

S.No.	Name of Professional Societies/ Chapters	Event and Title	Date of event
1	ISF	Workshop on "Robotics"	9/7/2021
2	IETE	Guest Lecture on "5G communication	26/7/2021
3	IETE	Guest Lecture on "Recent Trends in Optical Communication"	3/9/2021
4	IETE	Poster Competition on "Save Earth"	15/9/2021
5	IETE	Workshop on "Recent trends in Embedded System"	25/10/2021
6	ISTE	Workshop on "Nvidia Development for AI"	22/11/2021
7	ISTE	Seminar on "How to write research paper"	6/12/2021
8	IETE	Technical visit to AIR, Jabalpur	17/1/2022
9	ISF	Workshop on "Aurdino"	24/3/2022
10	ISTE	Webinar on "How to write a powerful resume"	31/3/2022
11	IETE	Workshop on "Image Processing using python"	2/4/2022
12	ISF	"Circuit Designing" Competition	6/4/2022
13	ISF	"C-puzzel" contest	16/4/2022

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5	AISHWARYA MISHRA	0206EC171008	PERSISTENT
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47	PRAGATI MEENA	0206EC171068	TCS
48	PRAKHAR NAGAR	0206EC171069	PERSISTENT
49	PRIYAL JAIN	0208CS171082	MINDTREE
50	PRIYANSHI SHUKLA	0206EC171070	COFORGE
51	RAGINI RAJAK	0206EC171071	COFORGE
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63	SHREEKUSH SUHANE	0206EC171088	CAPGEMINI
64	SHREYA SAHU	0206EC171089	TCS
65	SHREYA SINGH	0206EC171090	COFORGE
66	SHRI OM PATEL	0206EC183D06	MINDTREE
67	SHUBHAM KUMAR SINGH	0206EC171092	CERIUM SYSTEMS (P) LTD.
68	SHUBHANK SHUKLA	0206EC171095	DFE

69	SHUBHI JAIN	0206EX171048	COFORGE
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71	SNEHA TRIPATHI	0206EC171099	JIO
72	SUKHMANI KAUR BAKSHI	0206EC171100	JIO
73	SURBHI AWADHWAL	0206EC171101	CERIUM SYSTEMS (P) LTD.
74	SURBHI JAIN	0206EC171102	PERSISTENT
75	SWATI NEMA	0206EC171103	PERSISTENT
76	TANU DAVE	0206EC171104	COFORGE
77	TANYA VERMA	0206EC171105	JIO
78	VAISHNAVI KOSHTA	0206EC171106	CERIUM SYSTEMS (P) LTD.
79	VINEETA TIWARI	0206EC171109	TCS
80	VISHWAM TIWARI	0206EC171111	PERSISTENT
81	VIVEK SINGH CHOUHAN	0206EC171112	DONGFANG
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