Uninterrupted Power Supply Introduction for Technical Grade Staff

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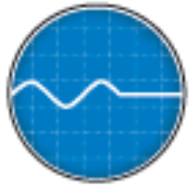
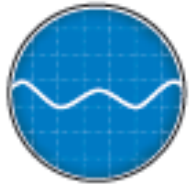
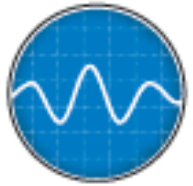
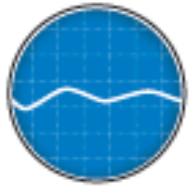
PART A

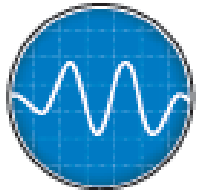
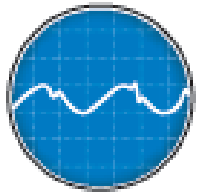
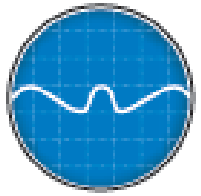
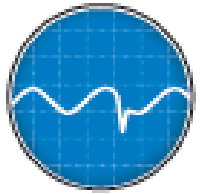
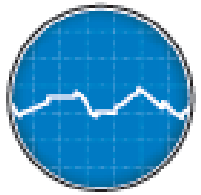
1. Introduction
2. Types
3. UPS Components
4. System Design
5. Associated Sub-system
6. System Redundancy
7. System Design Considerations
8. Risk Assessment
9. Safety Precaution

- **1. INTRODUCTION**
- An uninterruptible power supply (UPS) provides emergency power when the mains power fails.
- A UPS differs from an emergency power in that it will provide near-instantaneous protection from input power interruptions.
- A UPS is used to protect critical hardware.
  e.g.Computers, Data centers, Telecommunication equipment or Medical equipment.

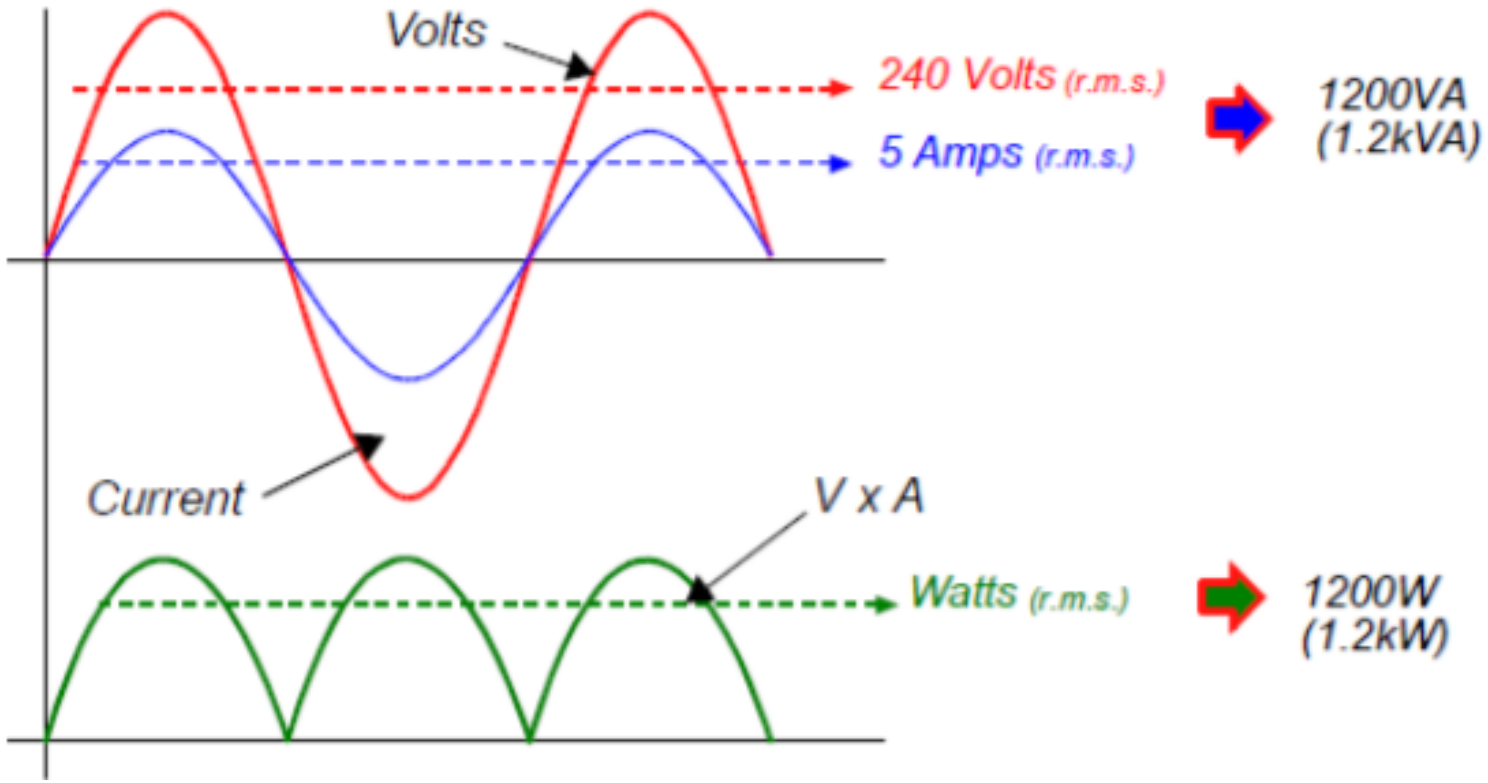
Common power problems

- Voltage spike, overvoltage and voltage sag
- Momentary or sustained reduction in input voltage
- Noise, high frequency transient or oscillation
- Instability of the mains frequency
- Harmonic distortion

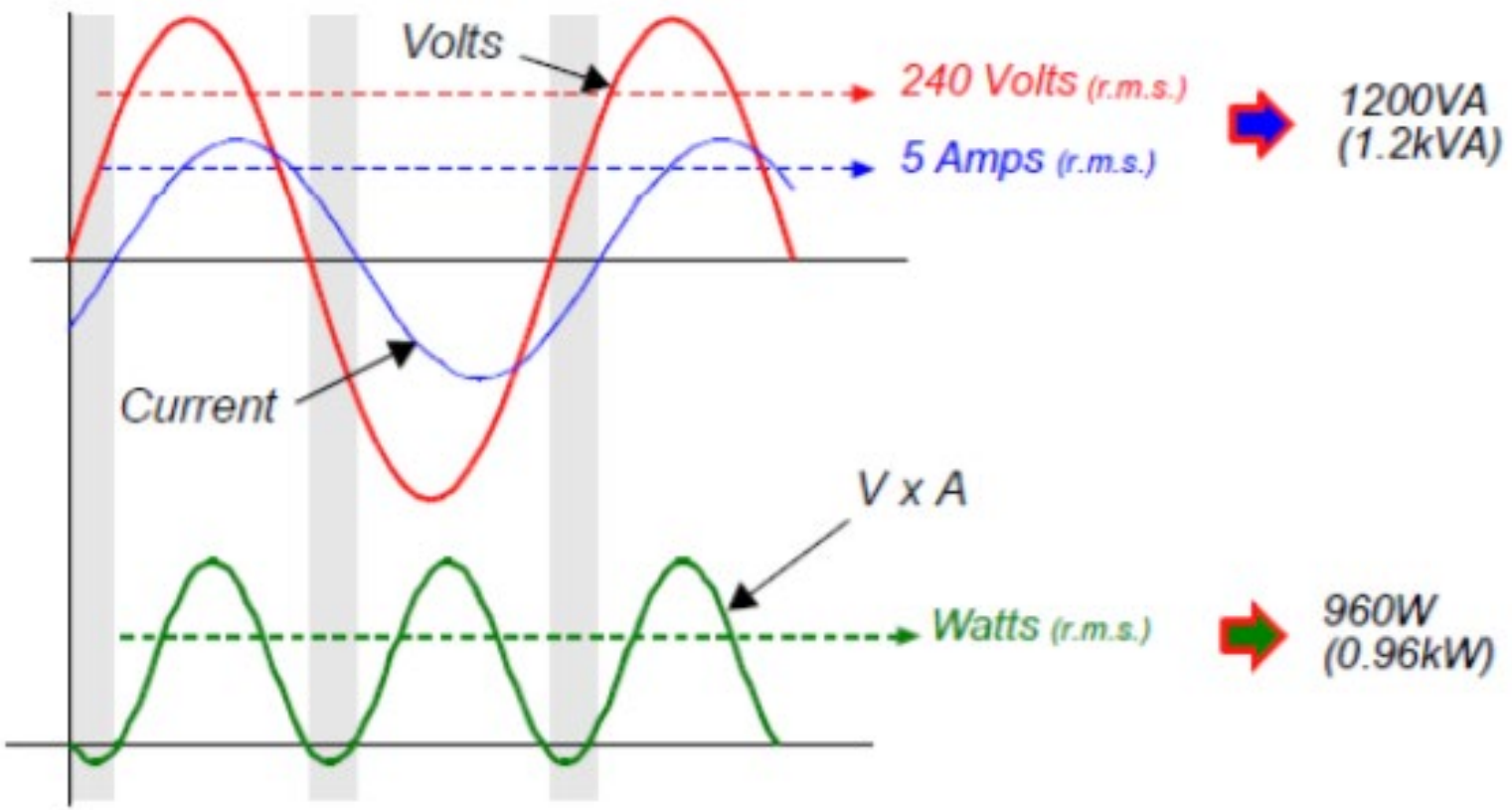
Power Problem		Definition
1	**Power failure** 	When a superhero loses his ability to fly or **a total loss of utility power.**
2	**Power sag** 	Post-lunch sleepiness or **short-term low voltage.**
3	**Power surge (spike)** 	Rush of energy following a double shot of espresso or **short-term high voltage more than 110 percent of normal.**
4	**Under-voltage (brownout)** 	When your amp's too wimpy to handle the bass line or **reduced line voltage for an extended period of a few minutes to a few days. Often happens during the summer months when everyone is cranking up their air conditioners.**

5	**Over-voltage**		Inhuman cheerfulness exuded by aerobics instructors or **increased line voltage for an extended period of a few minutes to a few days.**
6	**Electrical line noise**		Excuse you use to get off the phone quickly or **a high power frequency power wave caused by radio frequency interference (RFI) or electromagnetic interference (EMI).**
7	**Frequency variation**		Fluctuation in how often you do laundry from week to week or **a loss of stability in the power supply's normal frequency of 50 or 60 Hz.**
8	**Switching transient**		Breaking up with your significant other only to get back together every six months or **instantaneous under-voltage in the range of nanoseconds.**
9	**Harmonic distortion**		"Music" blaring from your nephew's headphones or **the distortion of the normal power wave, generally transmitted by unequal loads.**

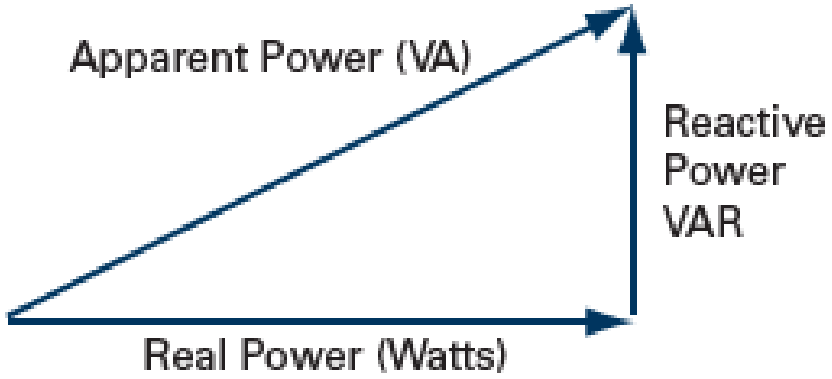
VA and Watts in a linear circuit



VA and Watts in a non-linear circuit



The difference between VA and watts



Watts =VA* Power Factor or VA=Watts/Power Factor

e.g 3KVA, Power Factor =0.8 , Watt =3kVa * 0.8=2400W

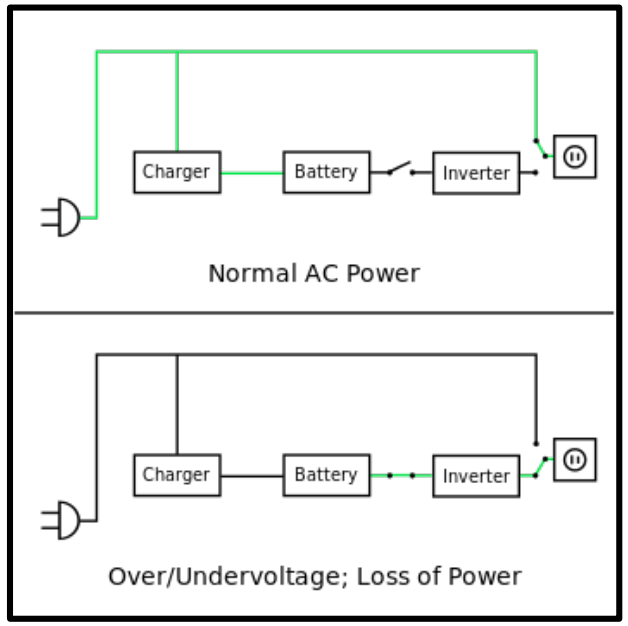
What does power factor mean?

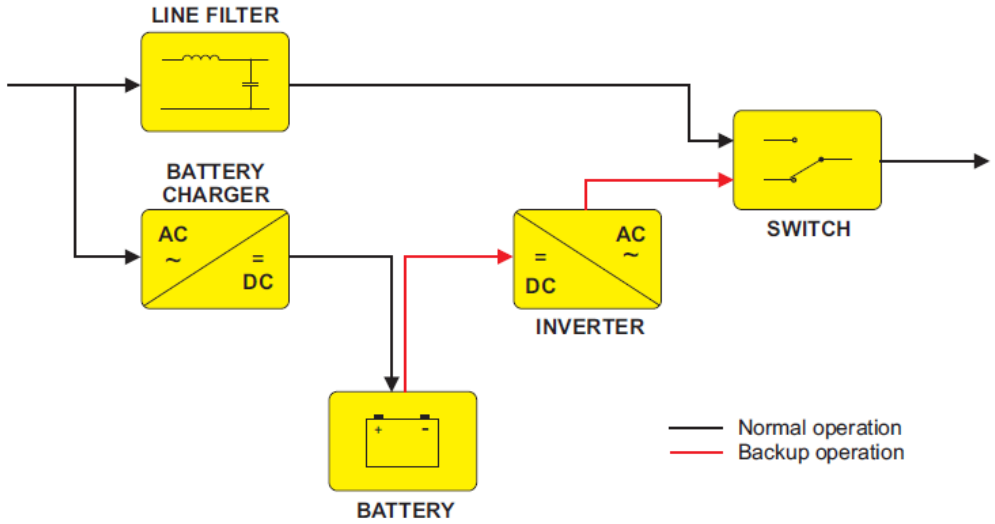
Power factor, also referred to as cosΦ is defined as the ratio of real power (KW) to apparent power (KVA). Unity power factor means cos 0° = 1, which in real terms simply means that KW = KVA, which therefore implies that KVAR = 0. So when cos$\Phi \rightarrow 1$, it reflects a very efficient usage of power consumed. When cosΦ = 0.85 or lower, it is considered low power factor,

2. Types

Three general categories of modern UPS systems

Standby / Offline

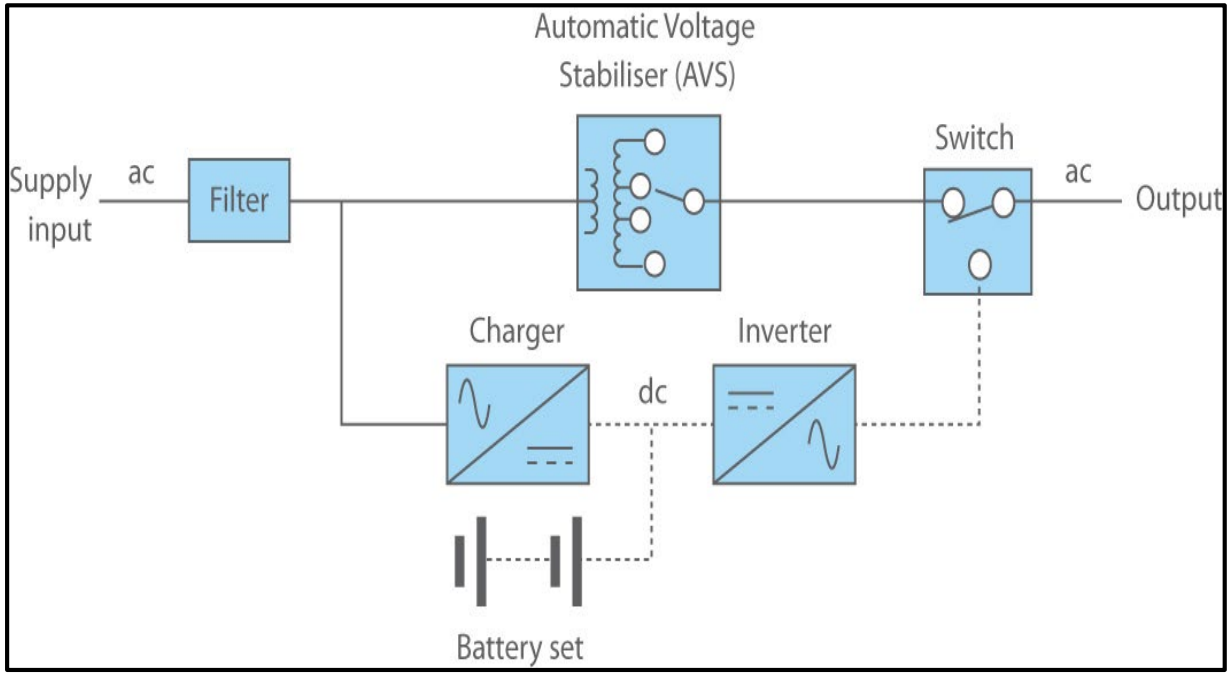


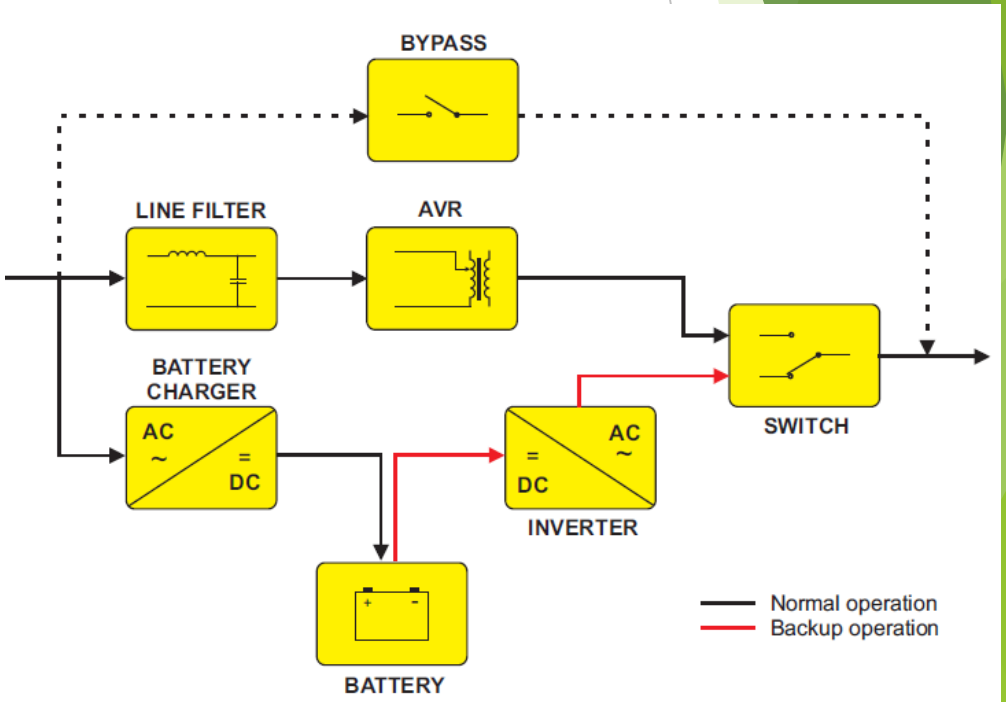


Line-interactive

Similarly to an Offline UPS, with the addition of a built-in Automatic Voltage Stabilizer (AVS). Typically a line-interactive UPS is only available up to 3kVA.

Most Line Interactive UPS will provide a modified sinewave whereas more premium designs will provide a sinewave output.





Online / Double-conversion

- The online UPS is ideal for environments where electrical isolation is necessary or for equipment that is very sensitive to power fluctuations.
- Reserved for very large installations of 10 kW or more.
- Necessary when the power environment is "noisy", when utility power sags, outages and other anomalies are frequent, when protection of sensitive IT equipment loads is required.
- It is called a *double-conversion* UPS due to the rectifier directly driving the inverter, even when powered from normal AC current.
- Online UPS typically has a static transfer switch (STS) for increasing reliability.

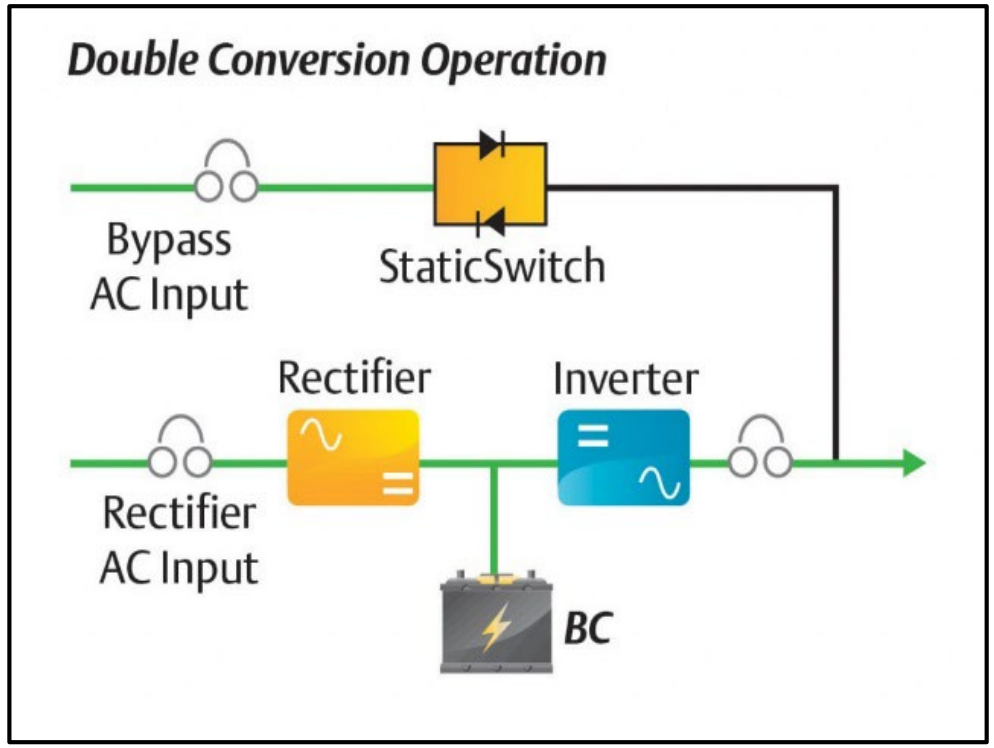
* In this chapter, we will focus on this type of UPS.

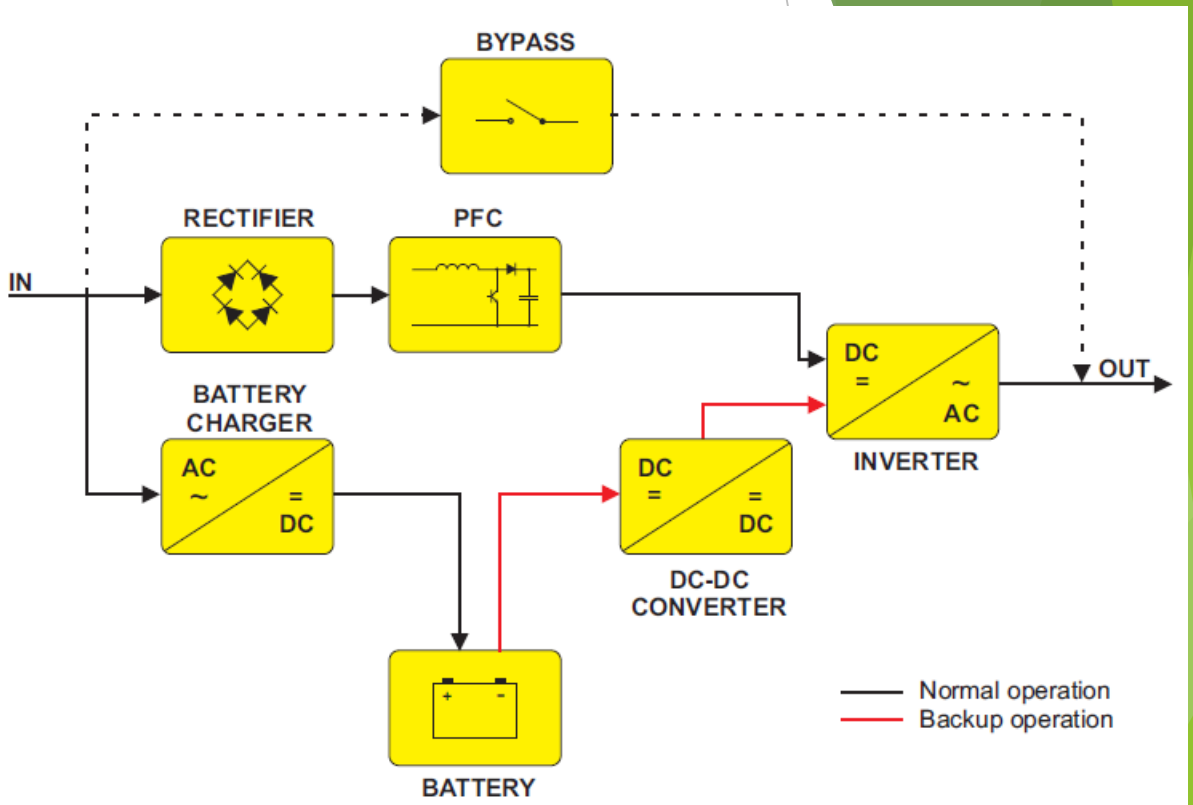
Power Problem	Online (VFI)	Line Interactive (VI)	Offline (VFD)
Sags/Brownouts	Yes	Yes	-
Surges	Yes	Yes	-
Spikes/Transients	Yes	Yes	Yes
Electrical Noise	Yes	Yes	Yes
Harmonics	Yes	-	-
Frequency Variation	Yes	-	-
Mains Failure	Yes	Yes	Yes

Comparisons between above UPS

1. **Offline Line / standby UPS** (VFD – Voltage and Frequency Dependent)
2. **Line Interactive UPS** (VI – Voltage Independent)
3. **Online / double conversion UPS** (VFI – Voltage and Frequency Independent)

- **Block Diagram of Double Conversion UPS**





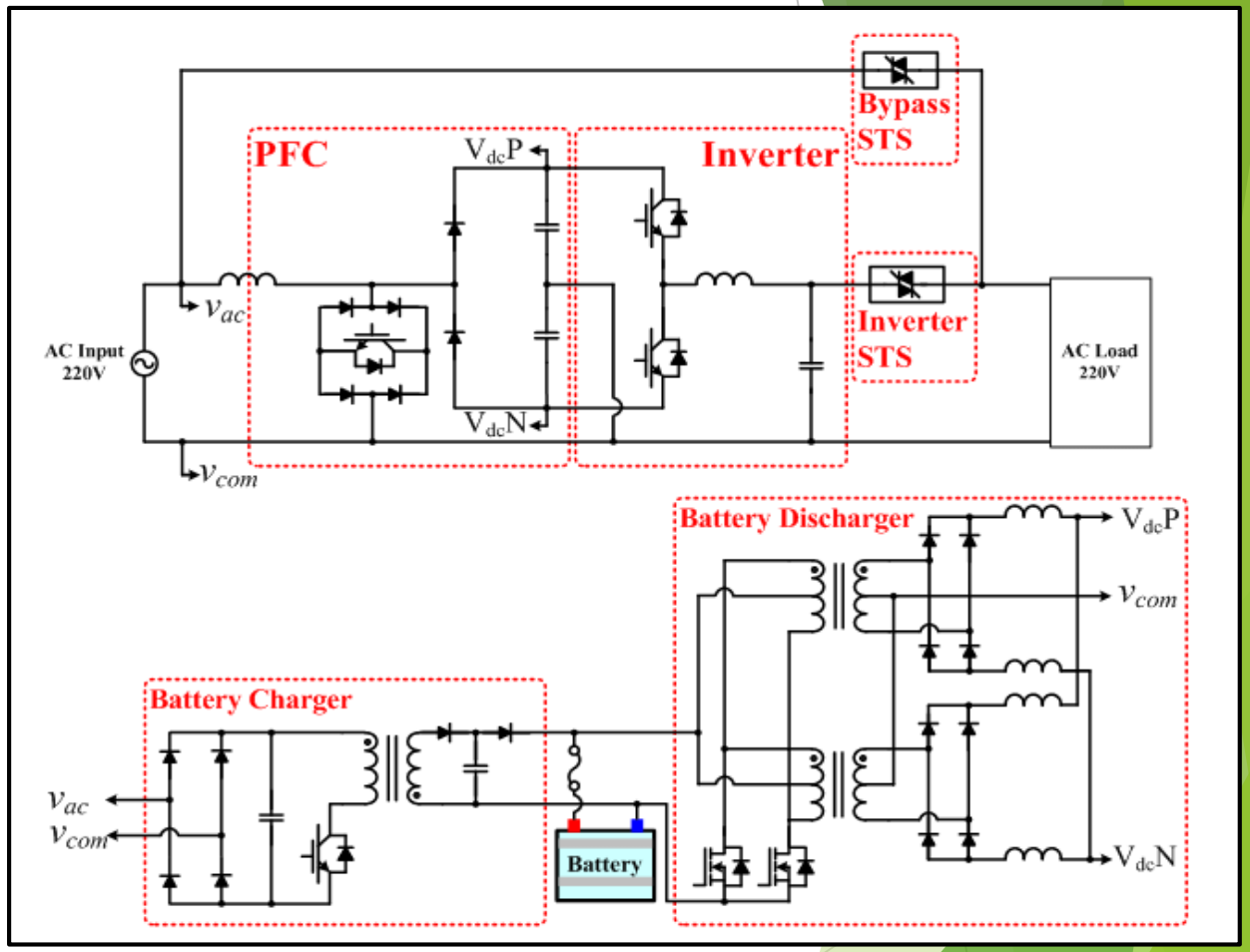
Block Diagram of Double Conversion UPS

3. UPS Components

Circuit Description

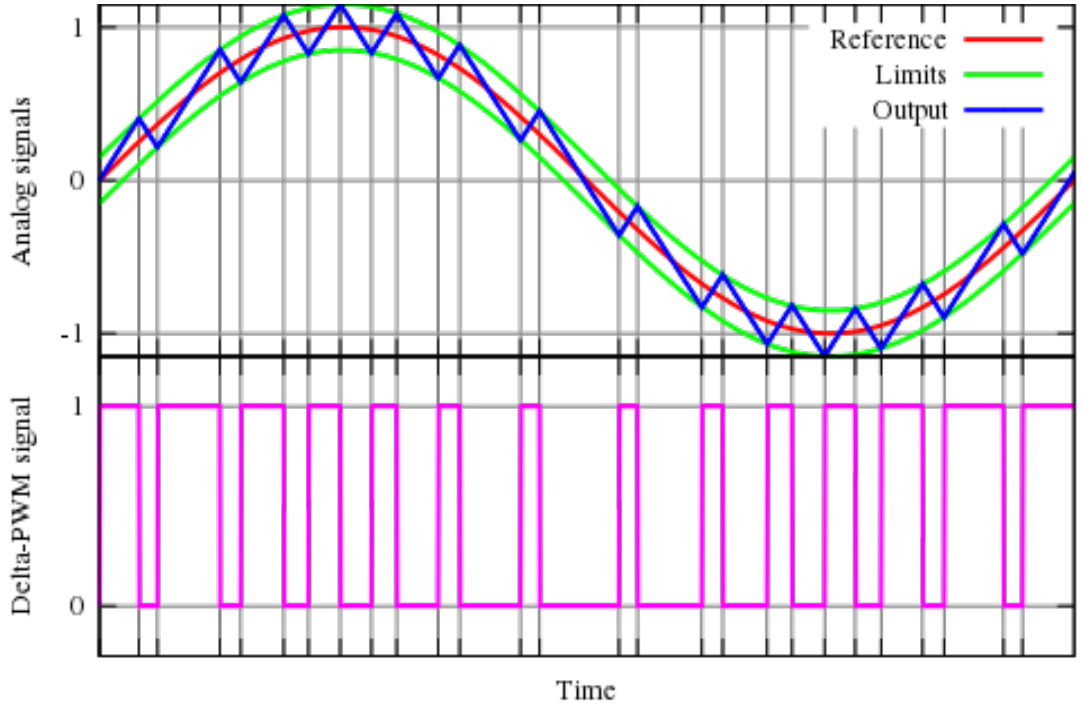
Power Factor Correction (PFC) and EMI Filter

- Rectifier
- Inverter
- Static Transfer Switch (STS)
- Battery Charger
- Battery Discharger (Battery Booster)
- Isolation Transformer (Optional Output Stage)



Technology (Pulse Width Modulation PWM)

- The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch.



Principle of the delta PWM. The output signal (blue) is compared with the limits (green). These limits correspond to the reference signal (red), offset by a given value. Every time the output signal (blue) reaches one of the limits, the PWM signal changes state.

IGBT the standard operation with a switching pattern to build up an output sine wave voltage.

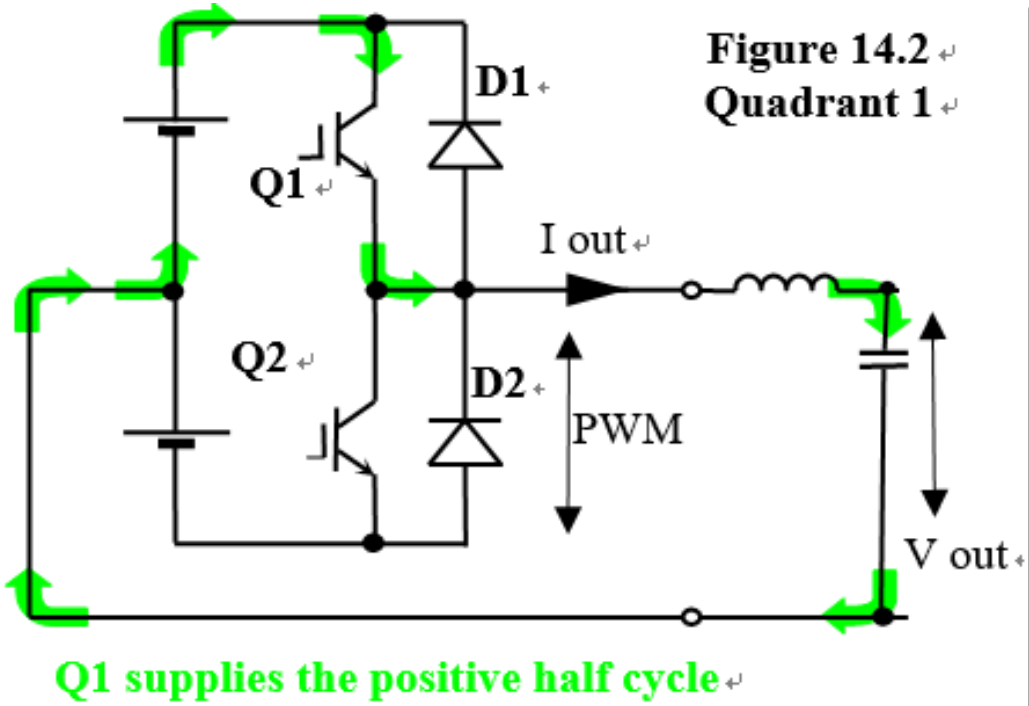
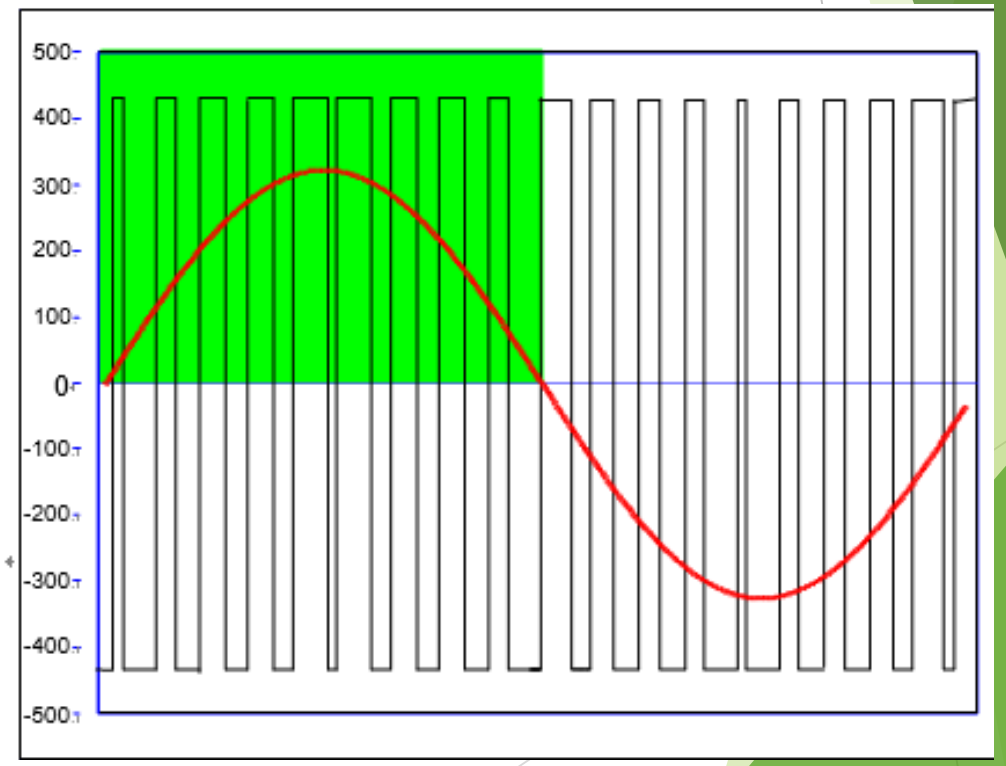


Figure 14.2
Quadrant 1



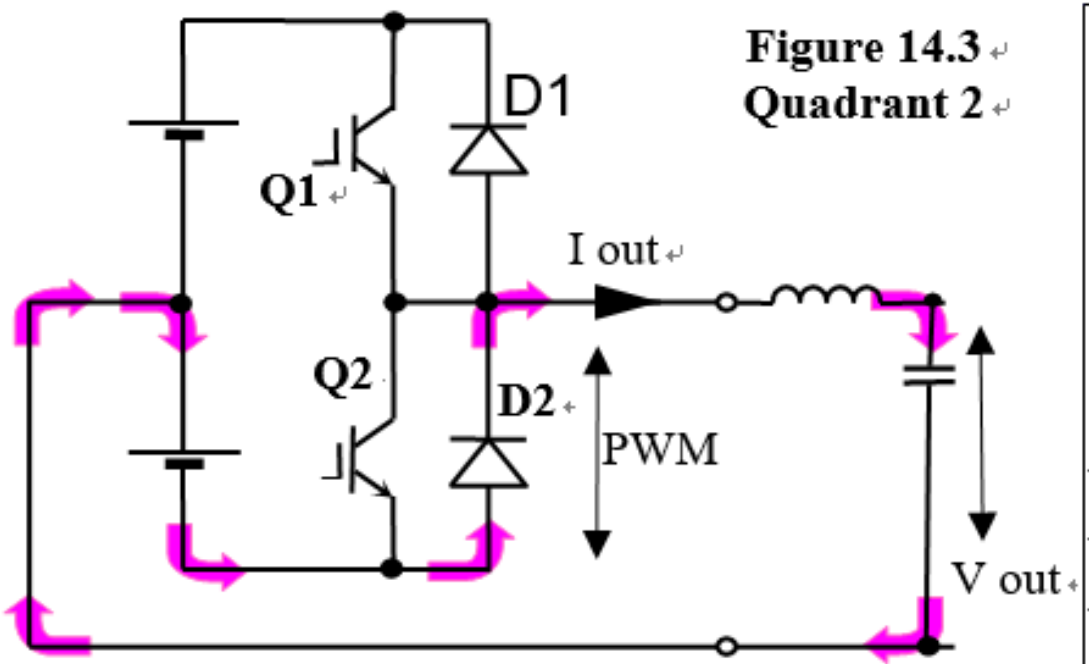
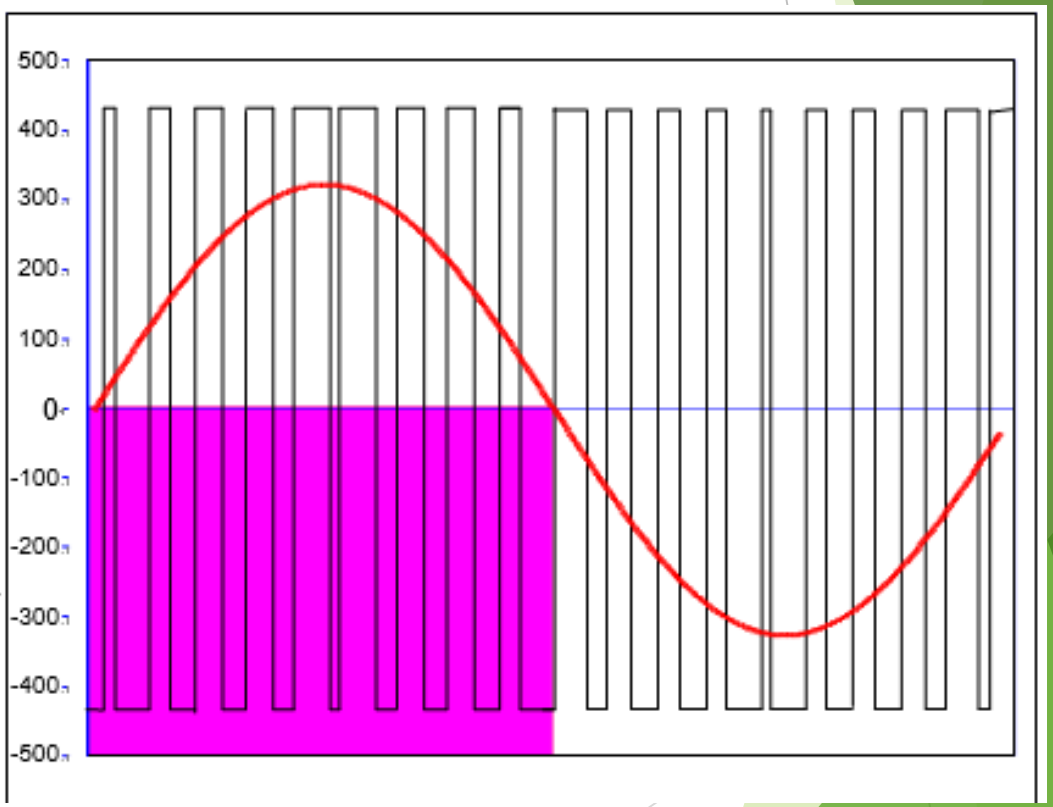


Figure 14.3
Quadrant 2



D2 provides a free-wheel path for the choke energy during the +ve half cycle

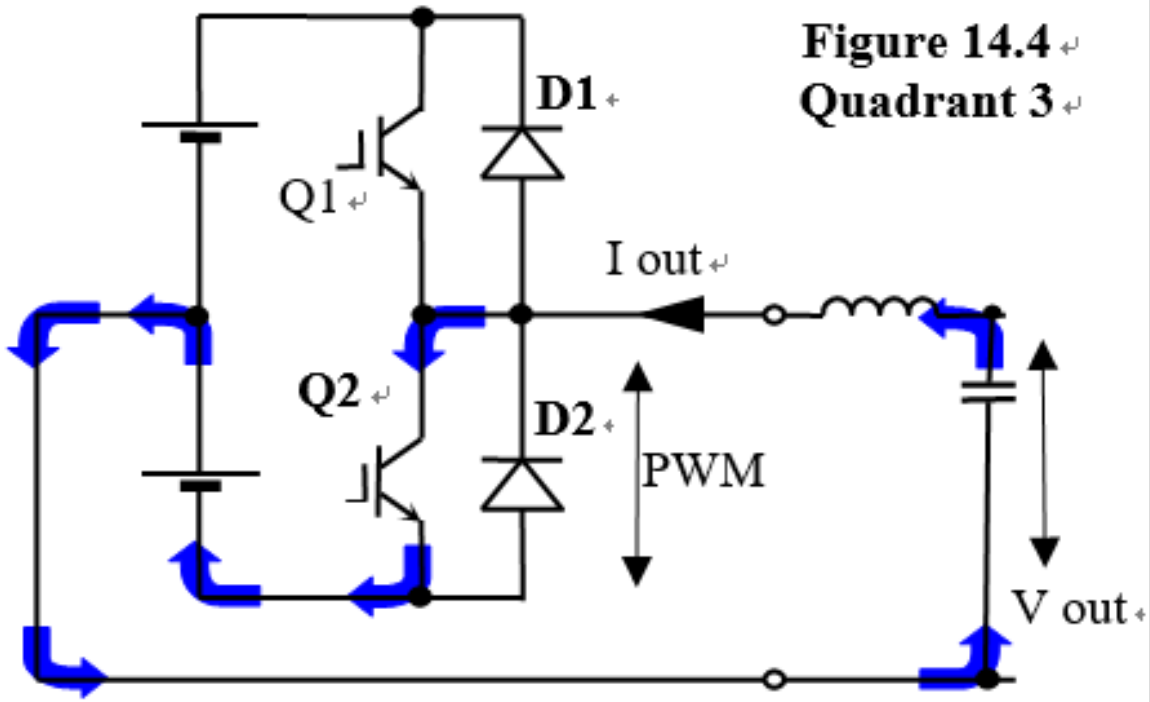
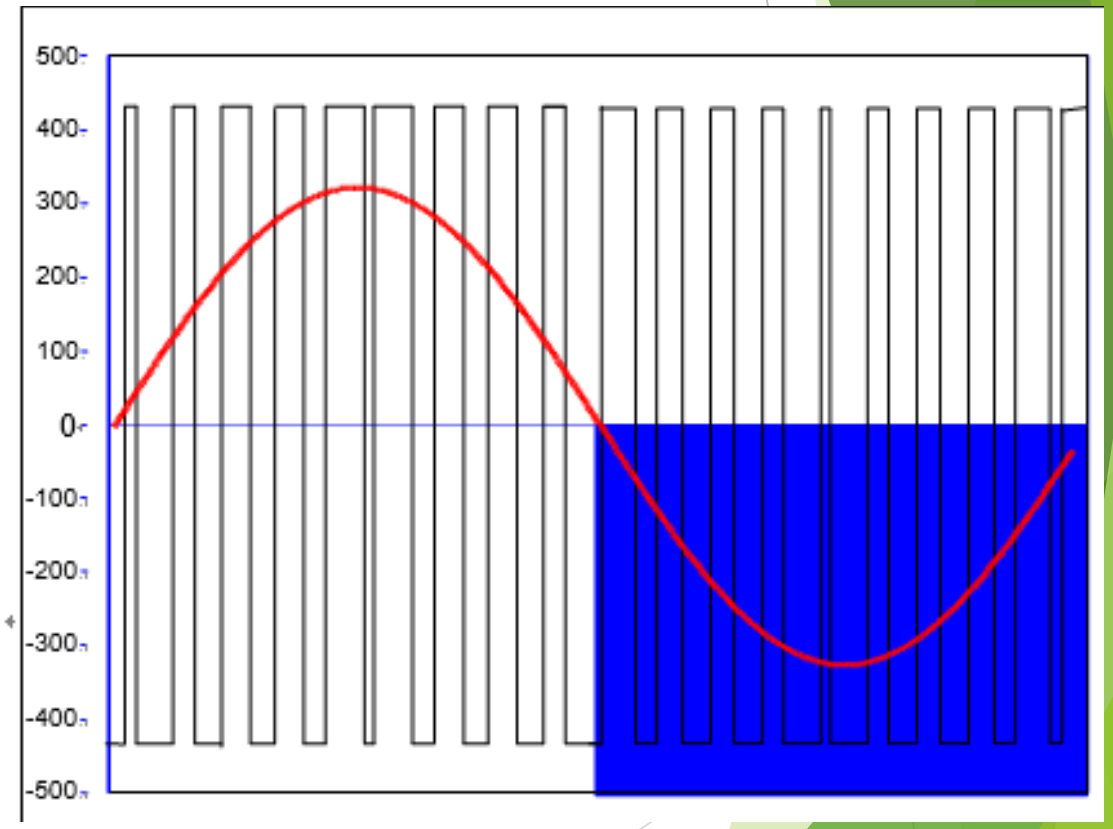


Figure 14.4
Quadrant 3

Q2 supplies the negative half cycle from the negative half battery



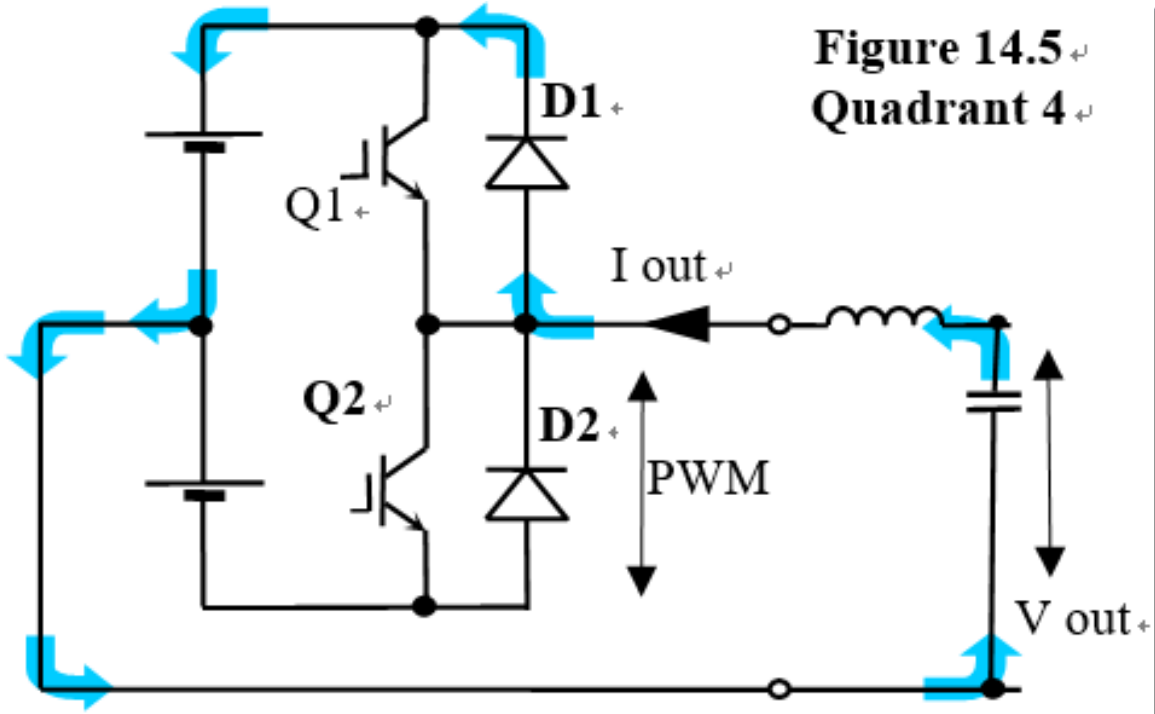
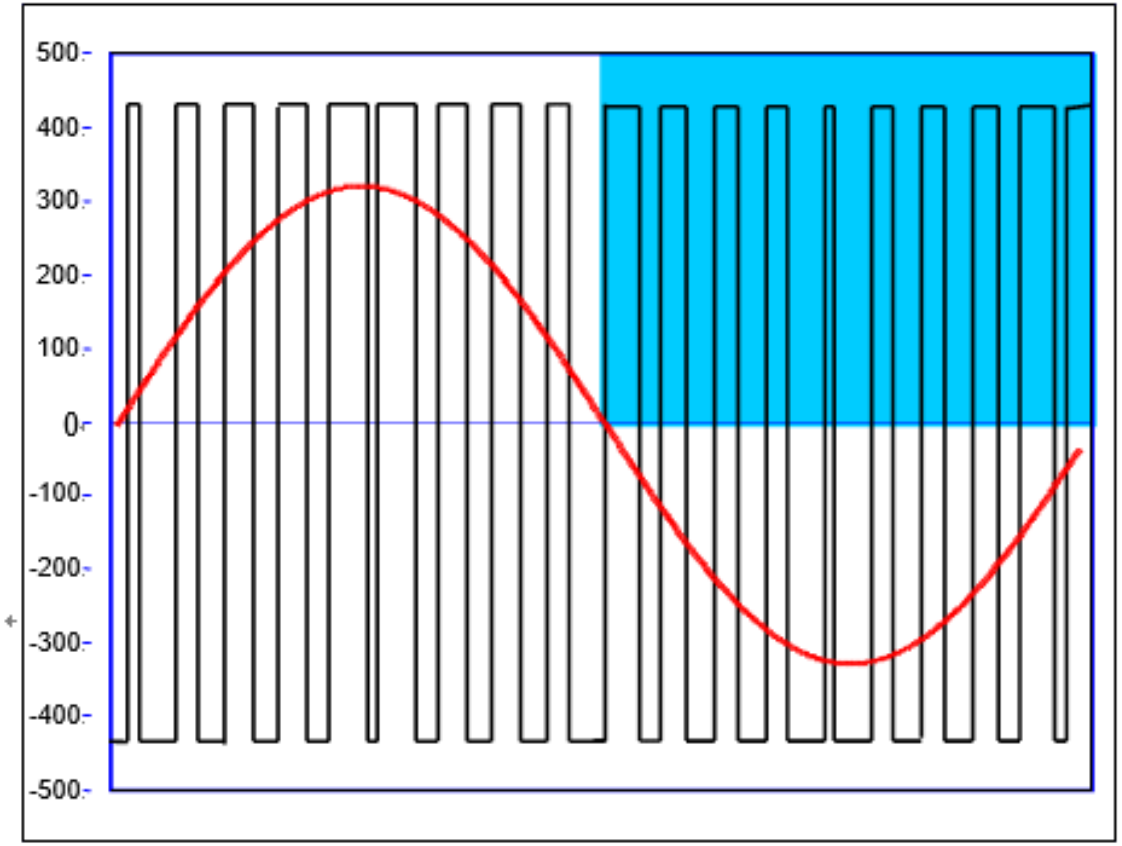
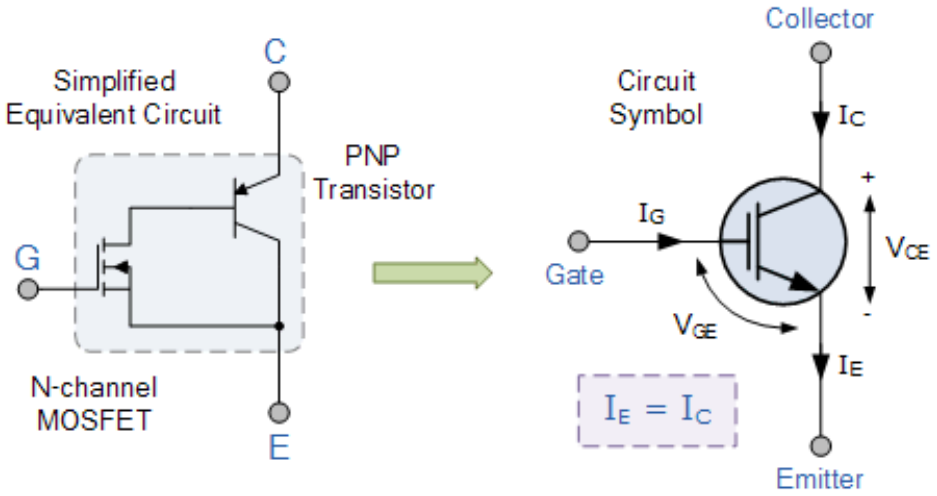


Figure 14.5
Quadrant 4

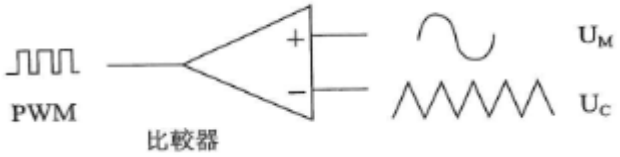


D1 provides a free-wheel path for the choke energy during the negative half cycle

Insulated Gate Bipolar Transistor



PWM



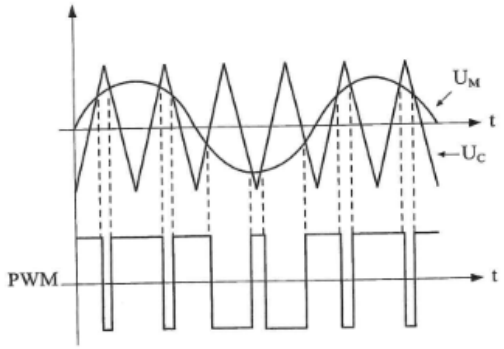


圖 3.10 PWM 的調制原理

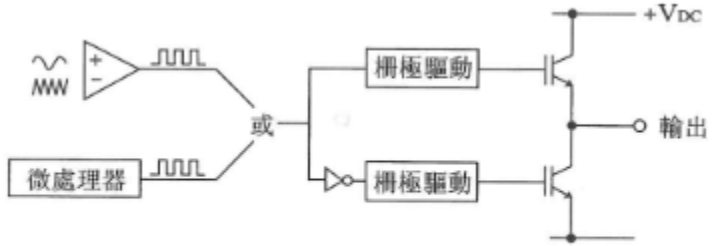
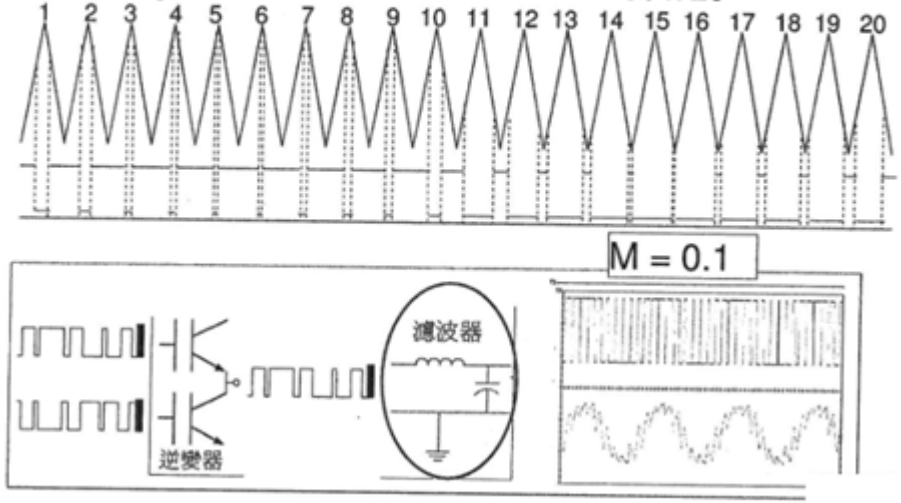
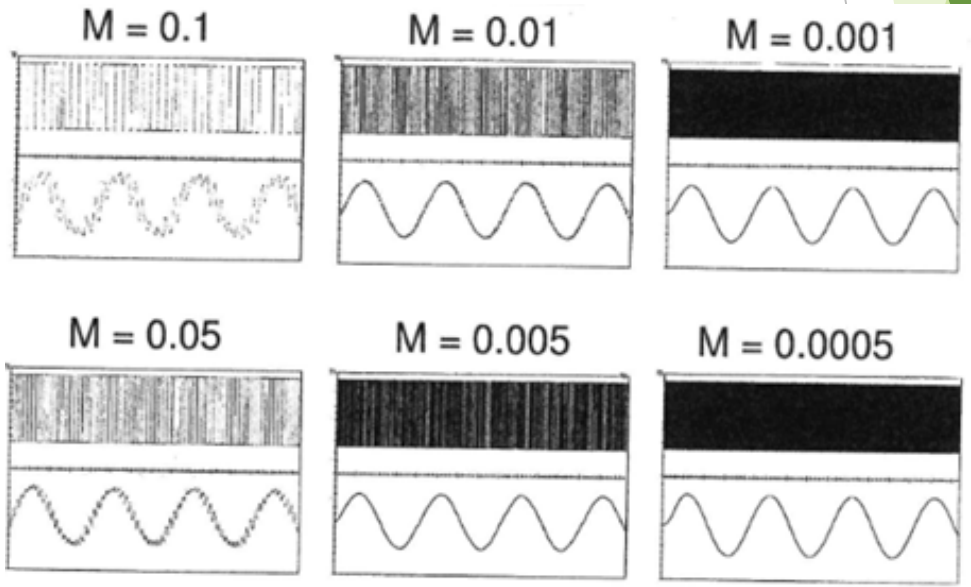


圖 3.12 柵極推動線路

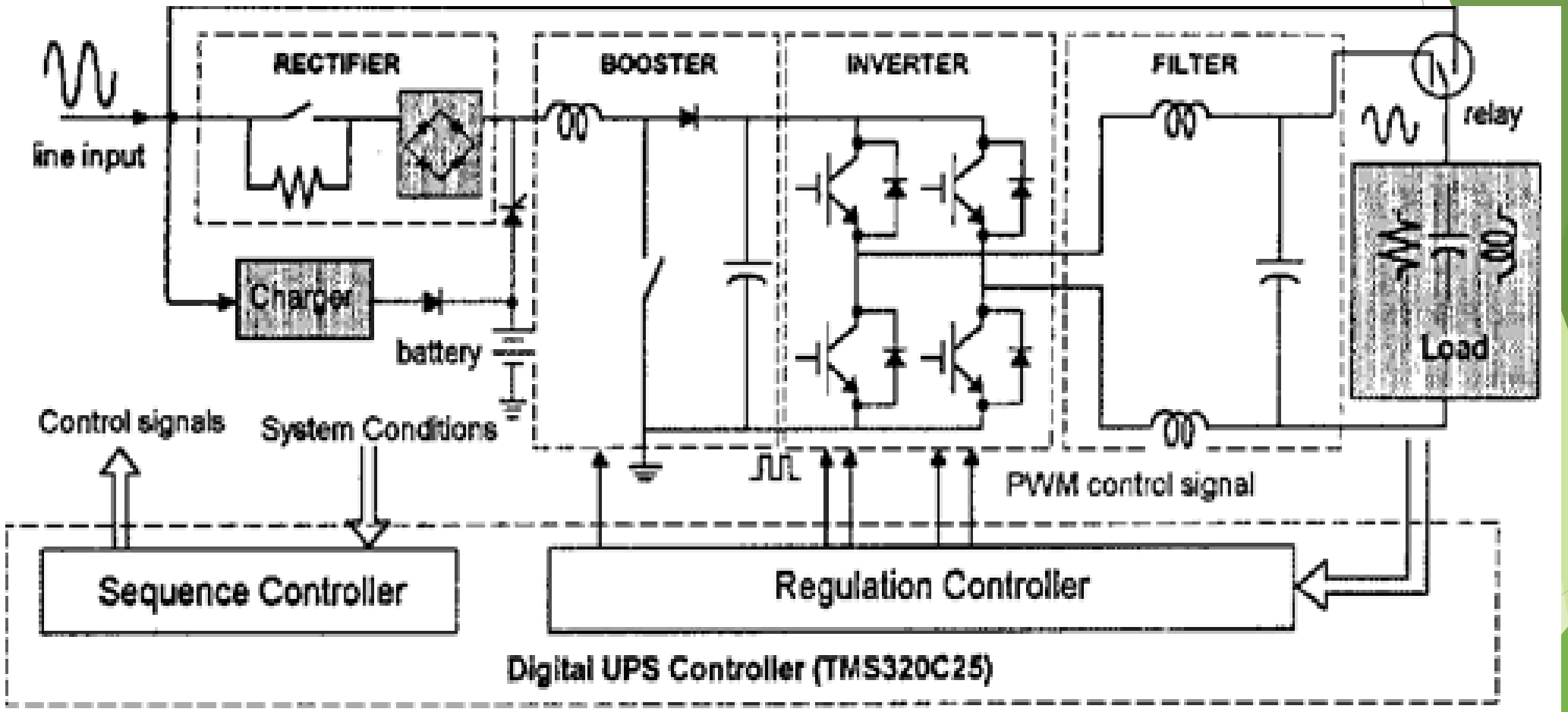
一台UPS輸出爲 step sine wave (步進正弦波)，U_C的值等於10至20，則調制指數 M 便是 0.1 至 0.05。

$$M = \frac{\hat{U}_M}{\hat{U}_C} = \frac{50Hz}{50 \times 10} = 0.1 \quad 至 \quad = \frac{50Hz}{50 \times 20} = 0.05$$





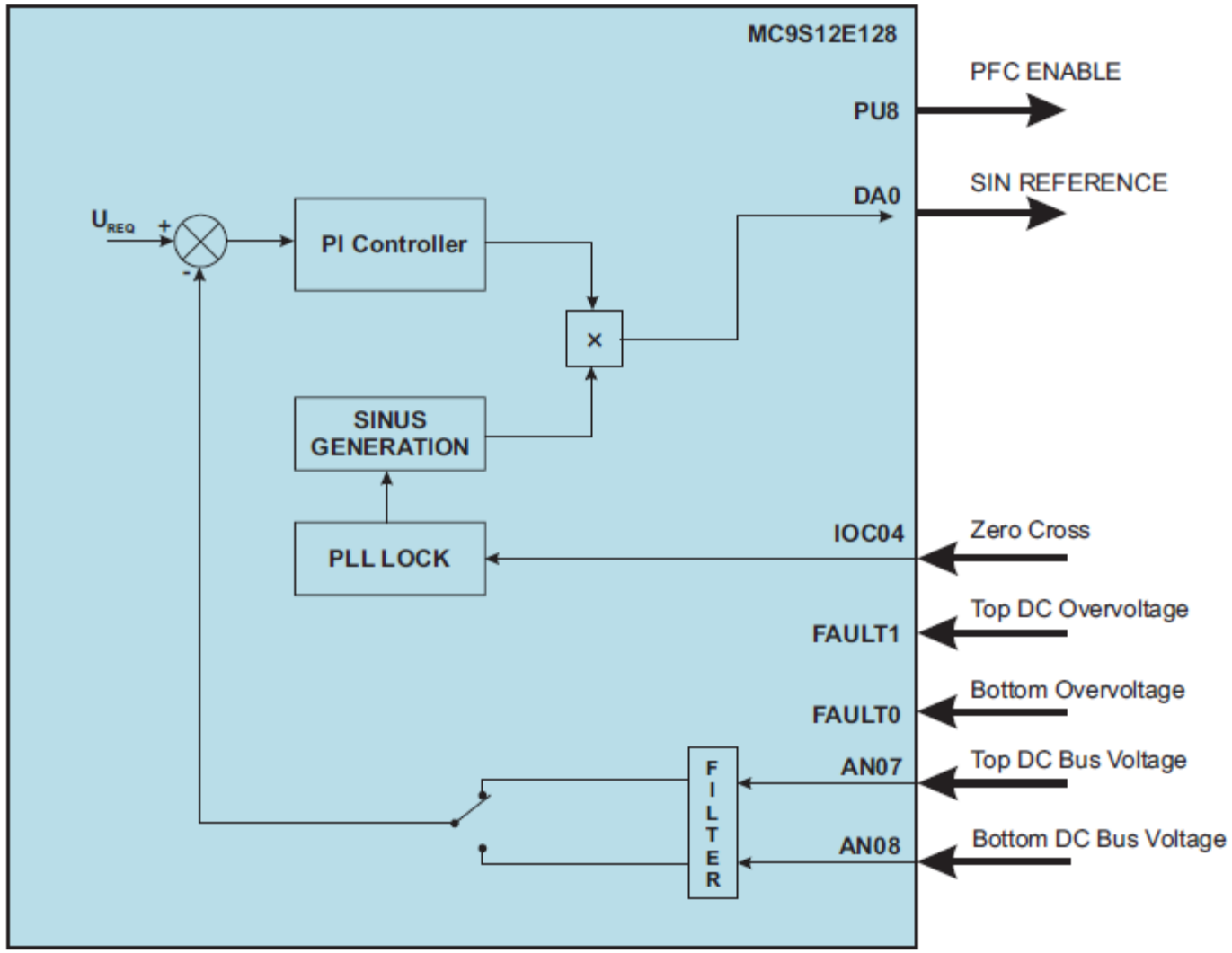
一台UPS輸出爲 true sine wave (真實正弦波)，U_C的值等於20000以上，則調制指數M便是0.00005。



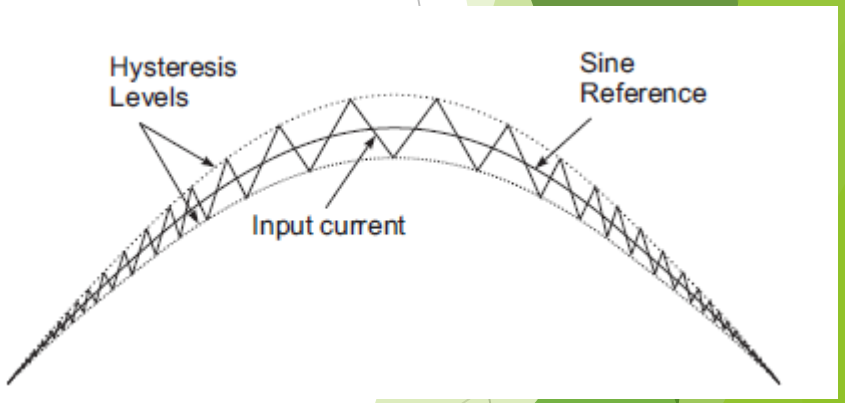
Schematic Block Diagram of a PWM UPS

NXP Single Phase On-Line UPS Using MC9S12E128 Reference Manual

Power Factor Correction Control
PFC Control Algorithm

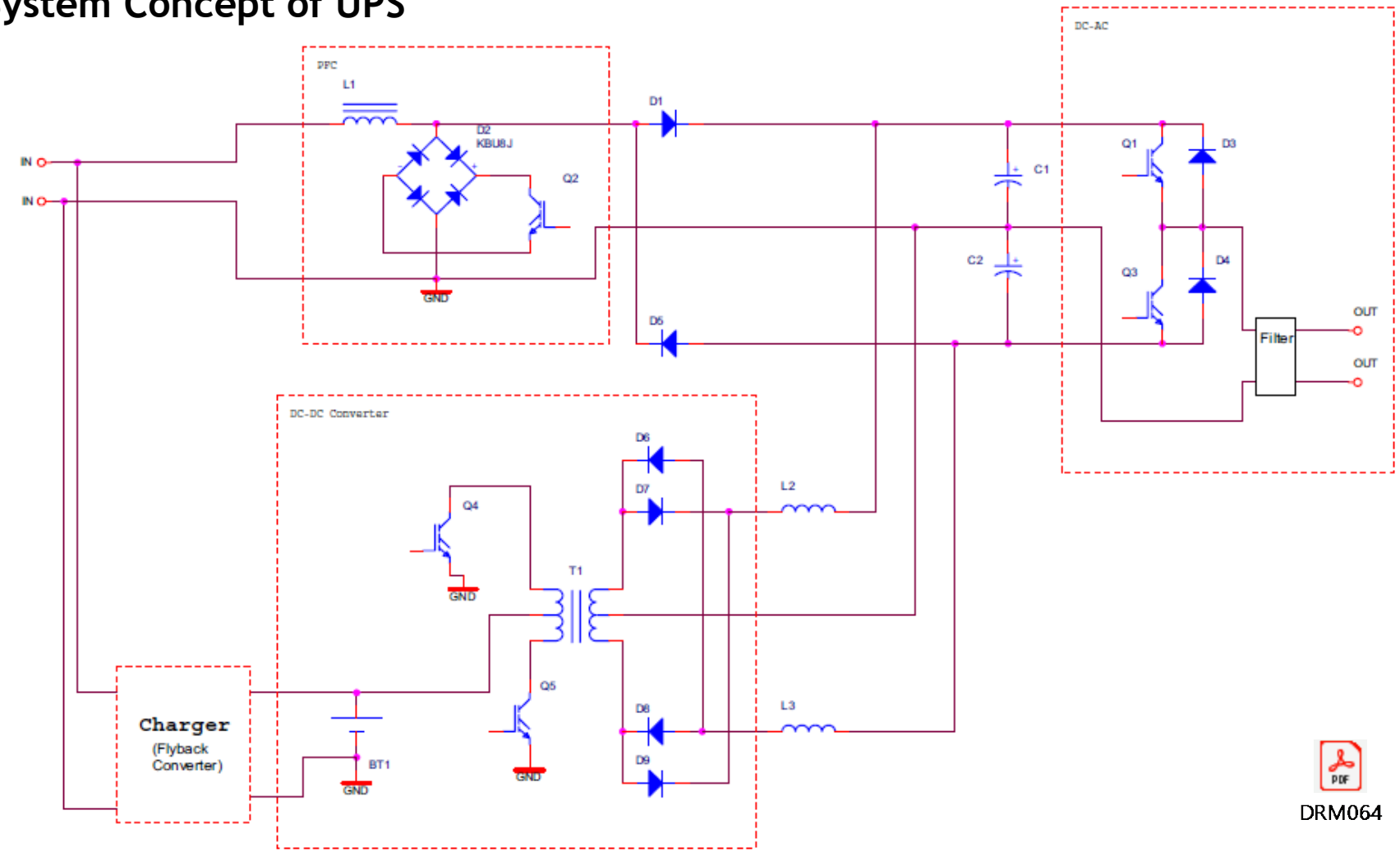


Hysteresis Control of Input Current



NXP Single Phase On-Line UPS Using MC9S12E128 Reference Manual

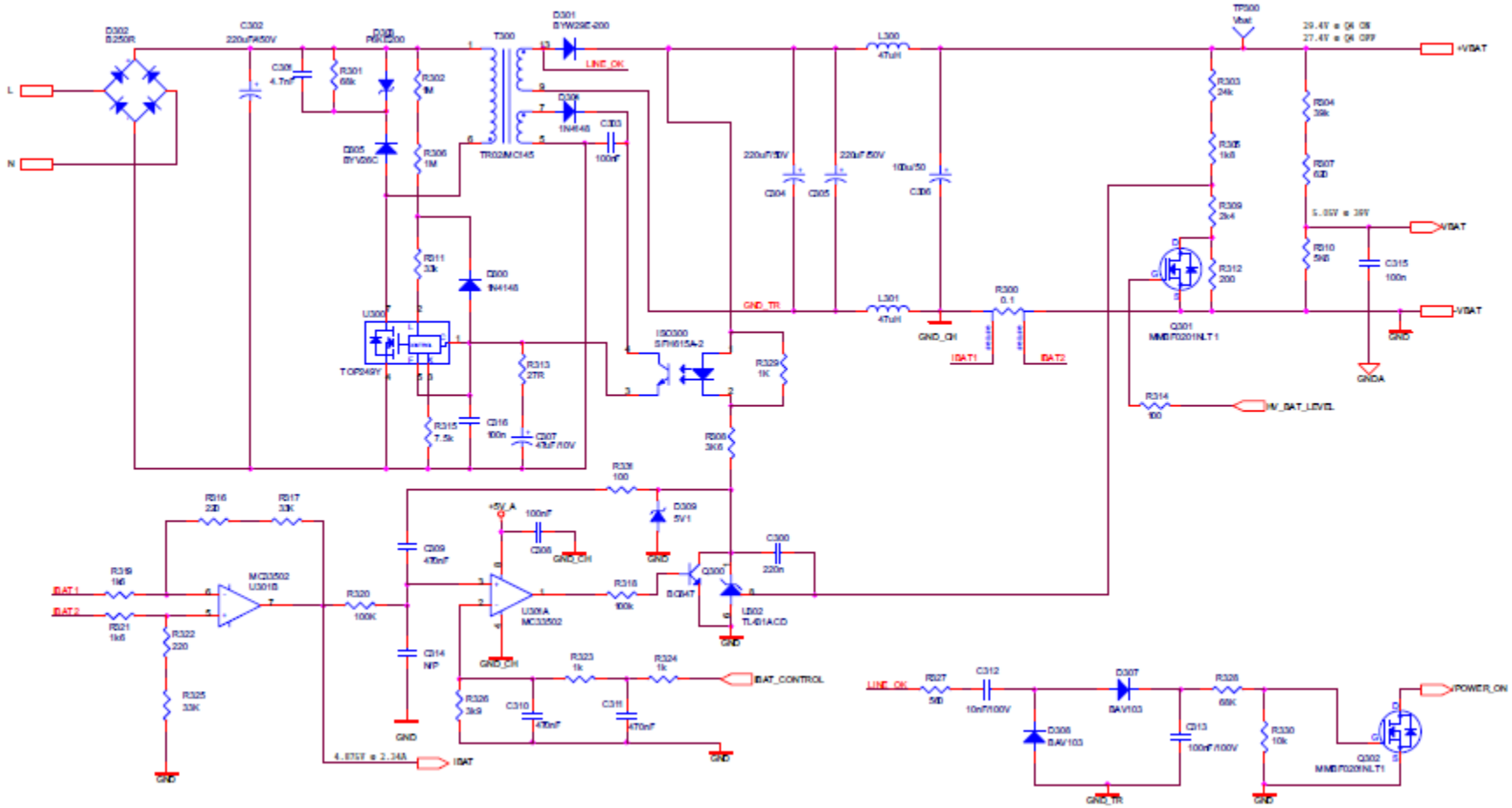
System Concept of UPS



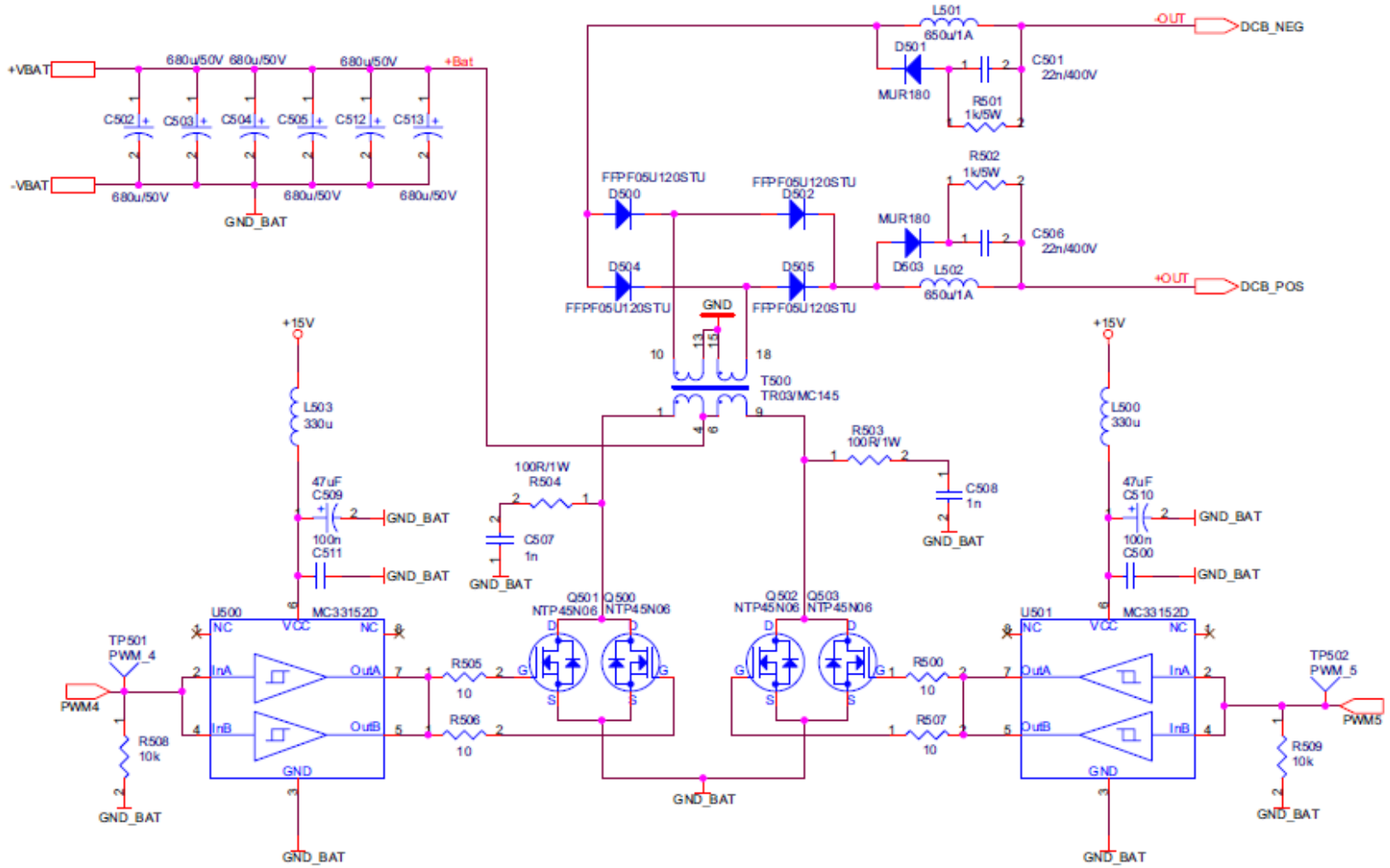
DRM064

Refer pdf P88,P89

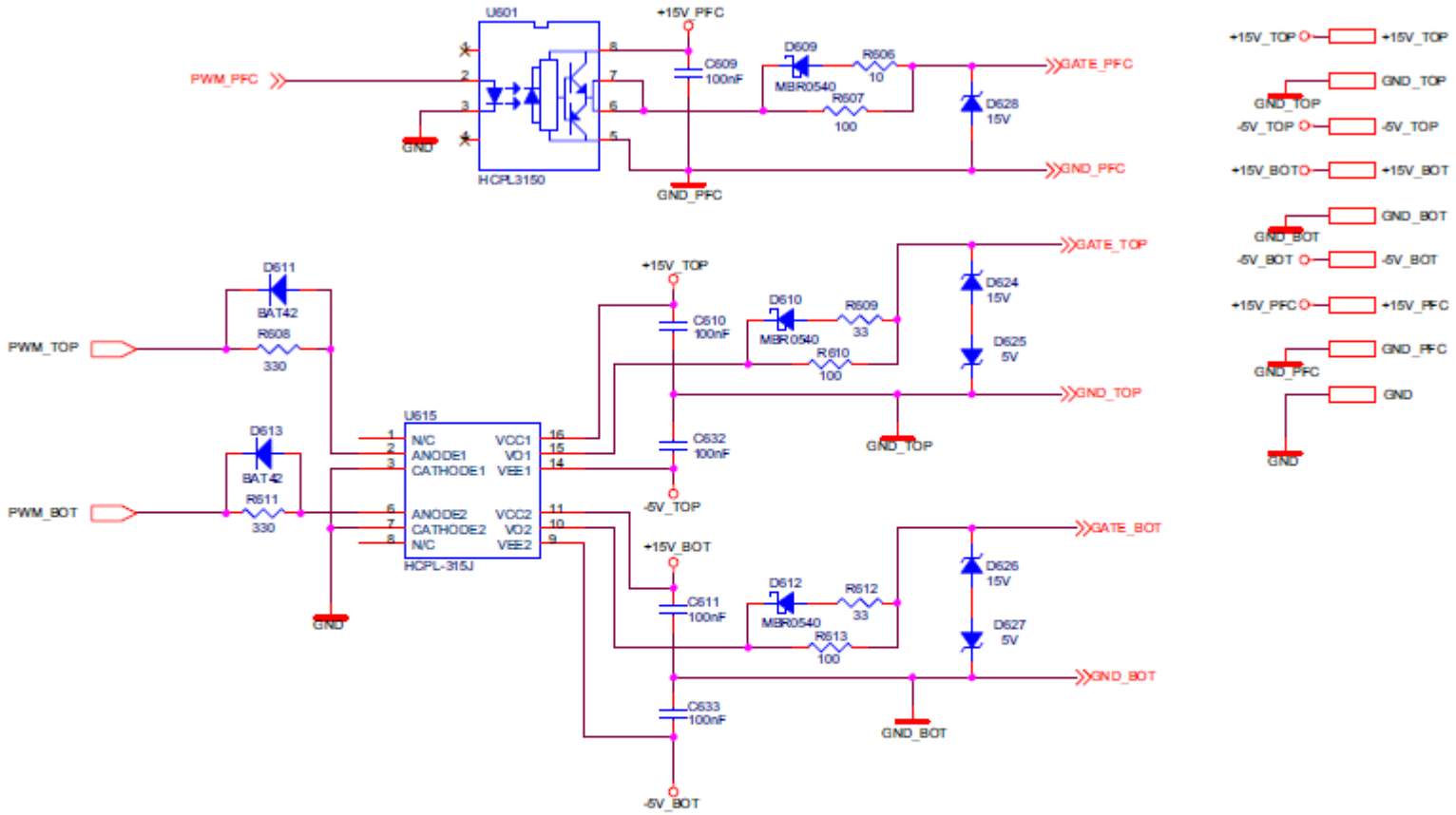
Battery Charger Schematics



dc/dc Converter Schematic

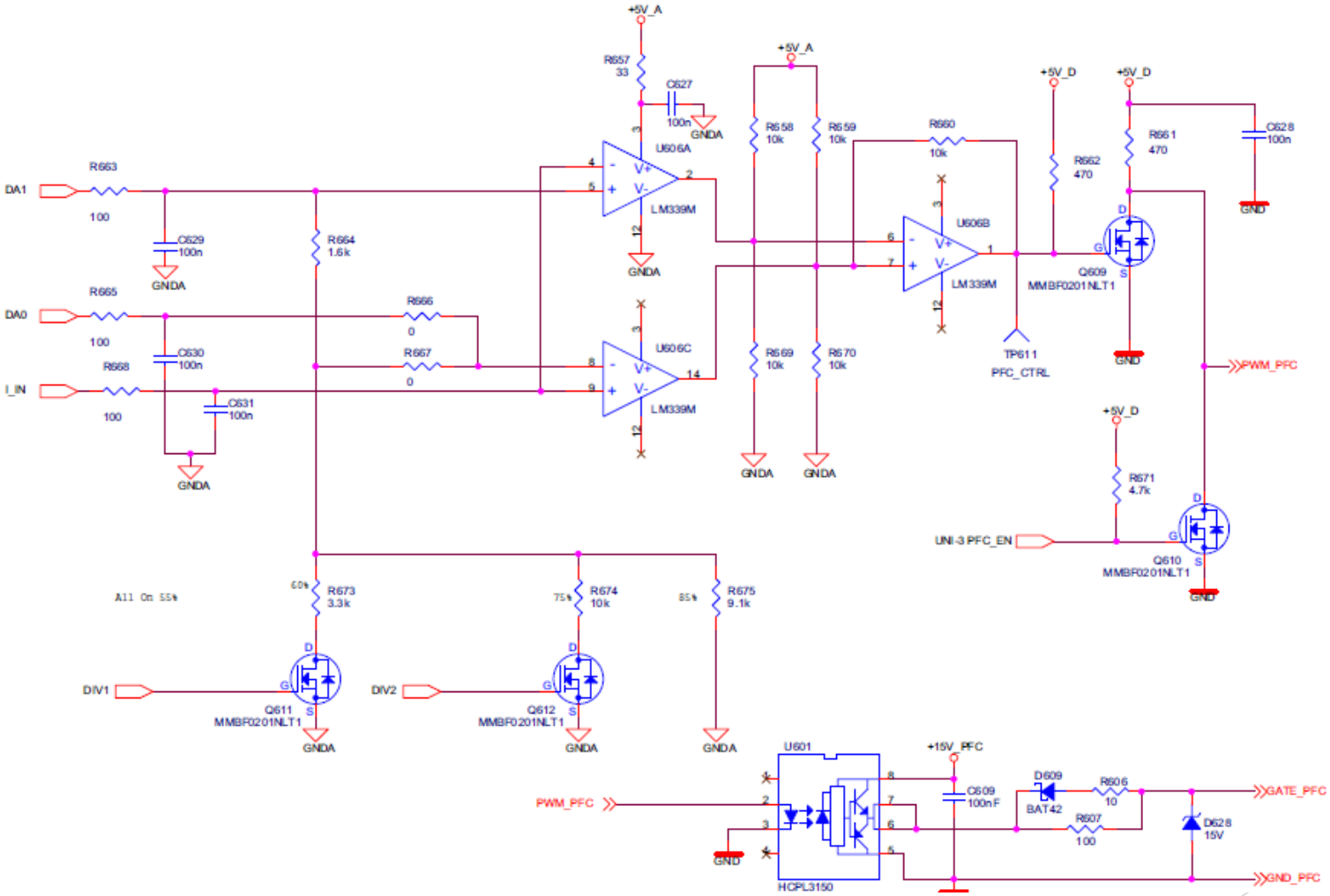


PFC and Inverter IGBT Drivers

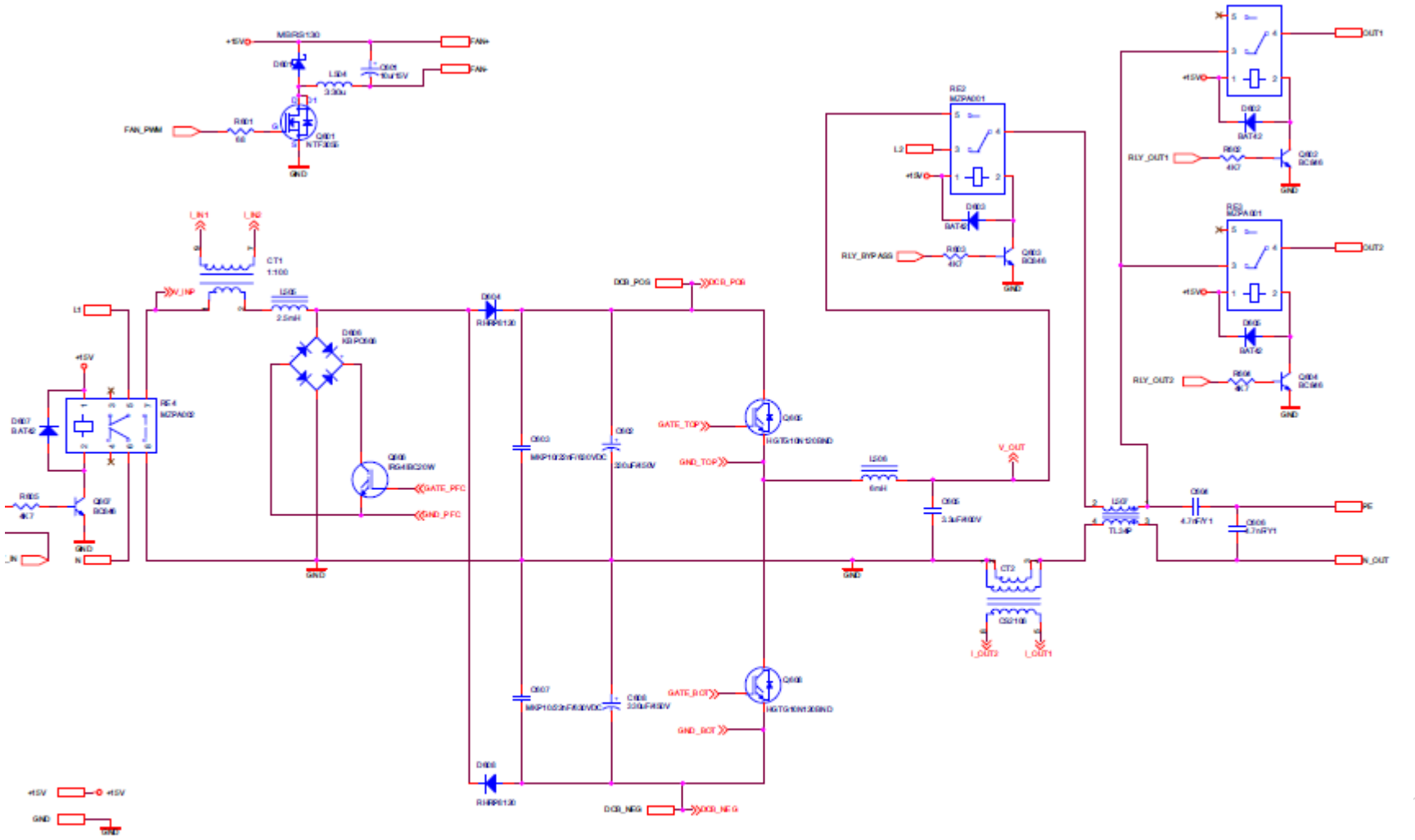


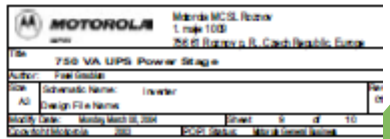
MOTOROLA MCSL	Motorola MCSL Roznov 1. maje 1009 756 61 Roznov p. R., Czech Republic, Europe	
Title: 750 VA UPS Power Stage		
Author: Pavel Grasblum		
Size: A4	Schematic Name: IGBT_Drives Design File Name:	Rev: 01
Modify Date: Monday, March 08, 2004	Sheet 8 of 10	
Copyright Motorola 2003	POPI Status: Motorola General Business	

PFC Current Controller

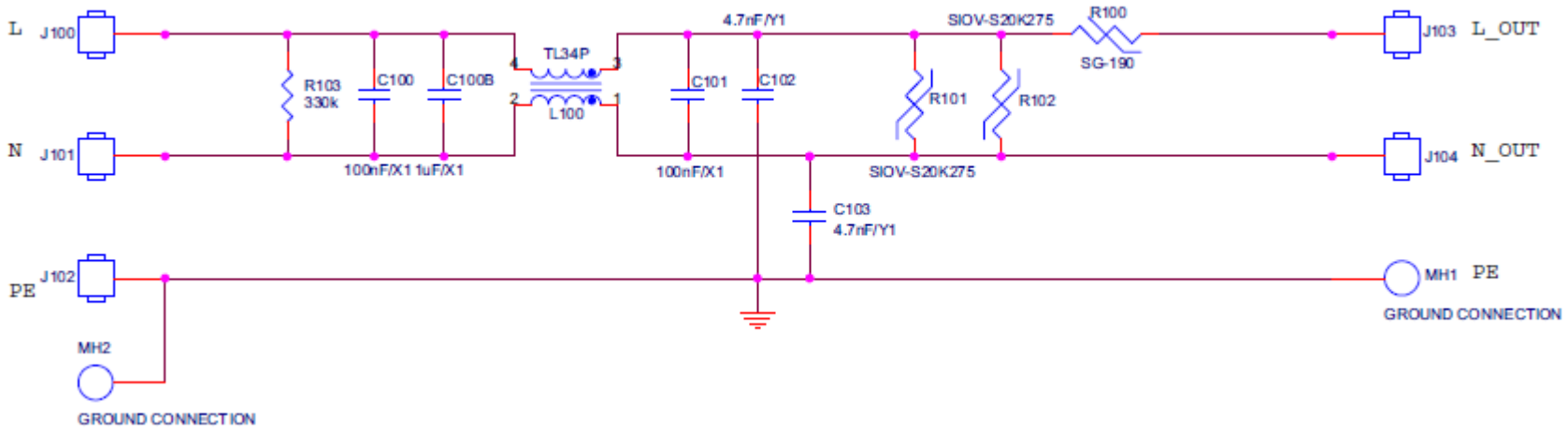


PFC and Inverter

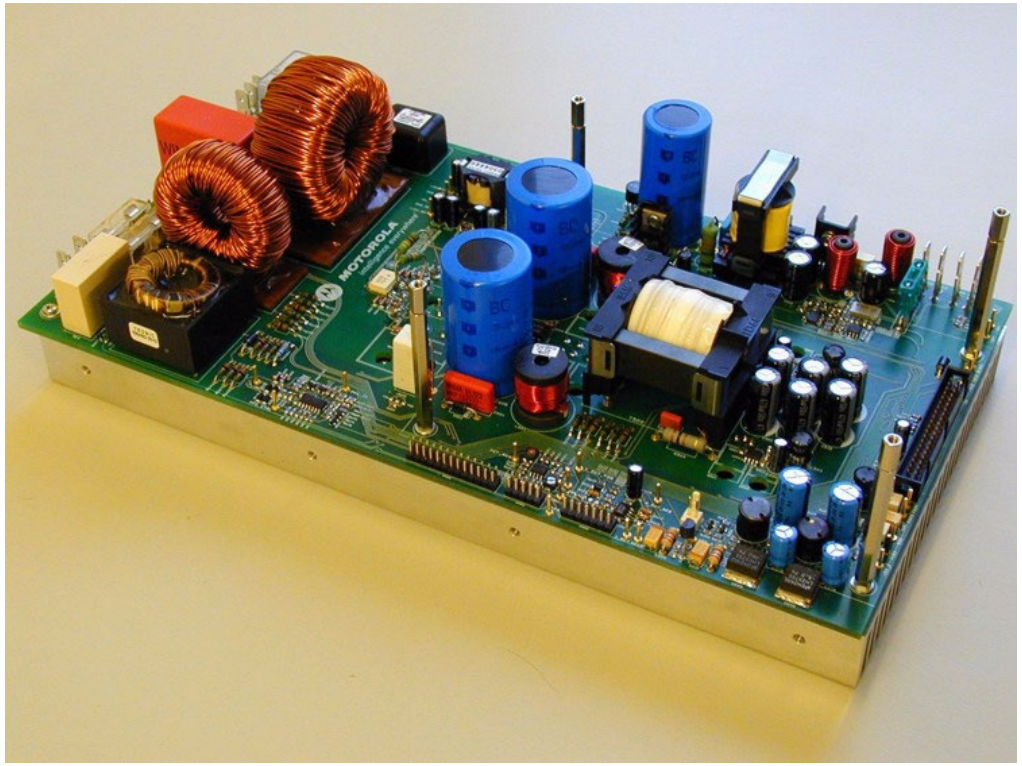




Schematics of Input Filter

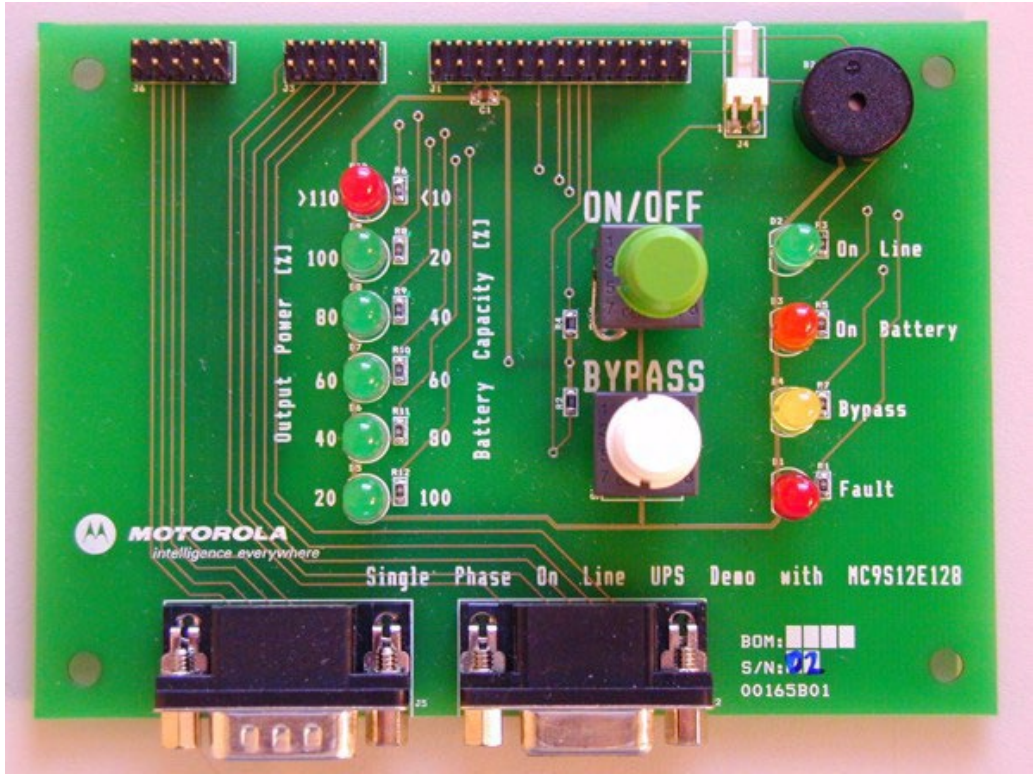


UPS Power Stage

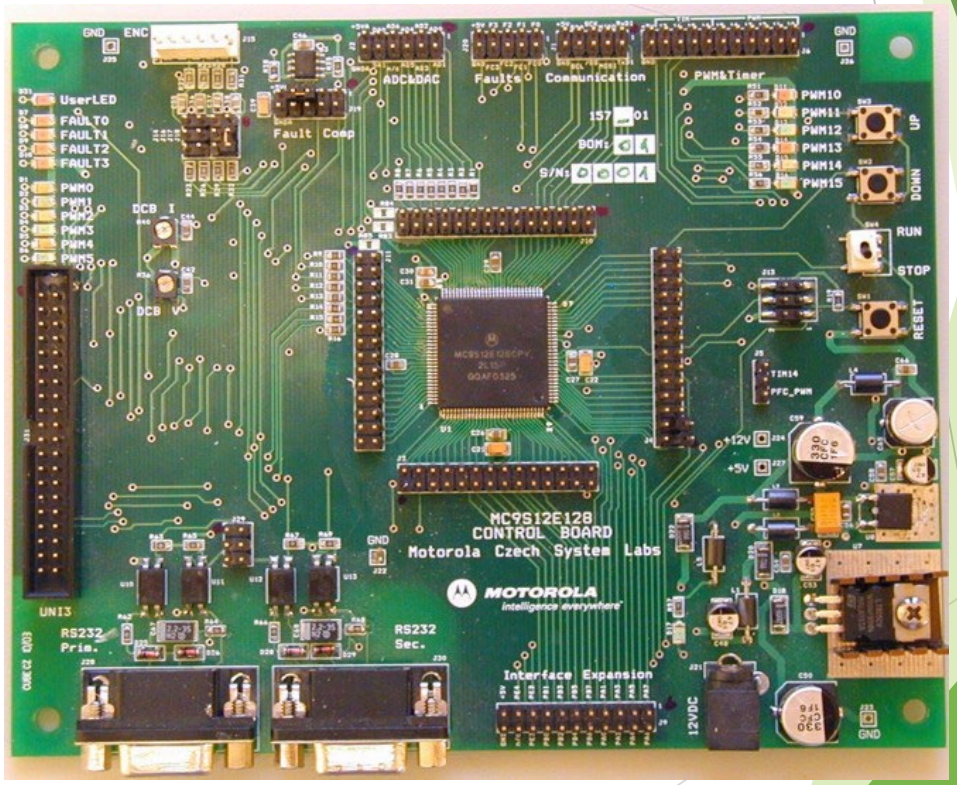


Input Filter

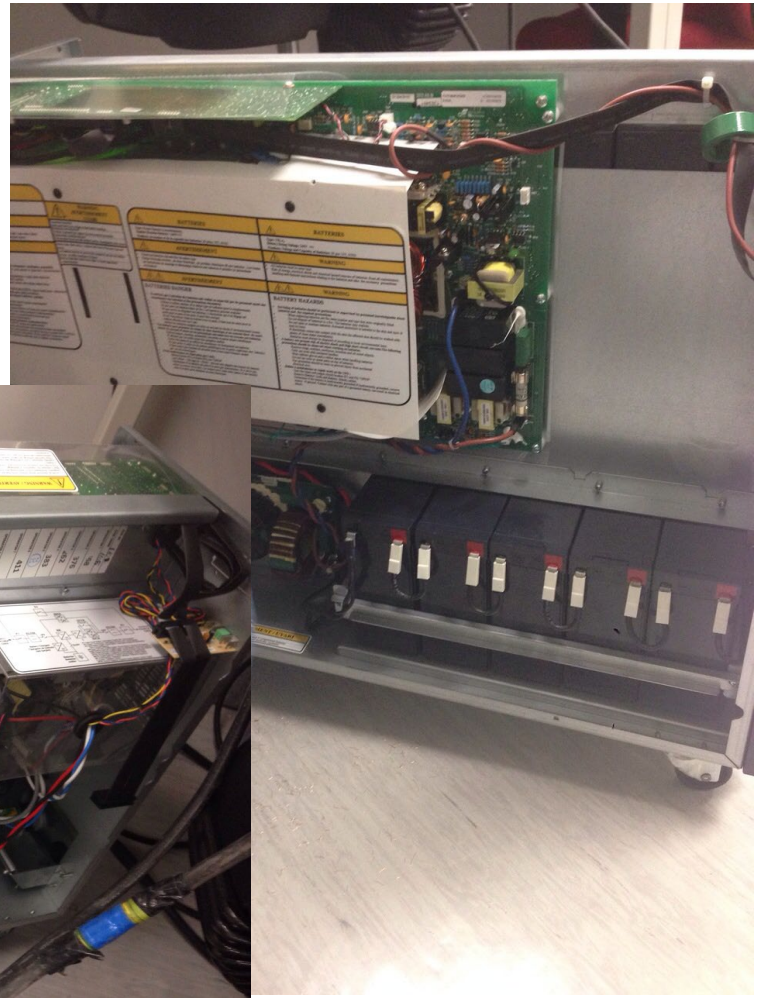
User Interface



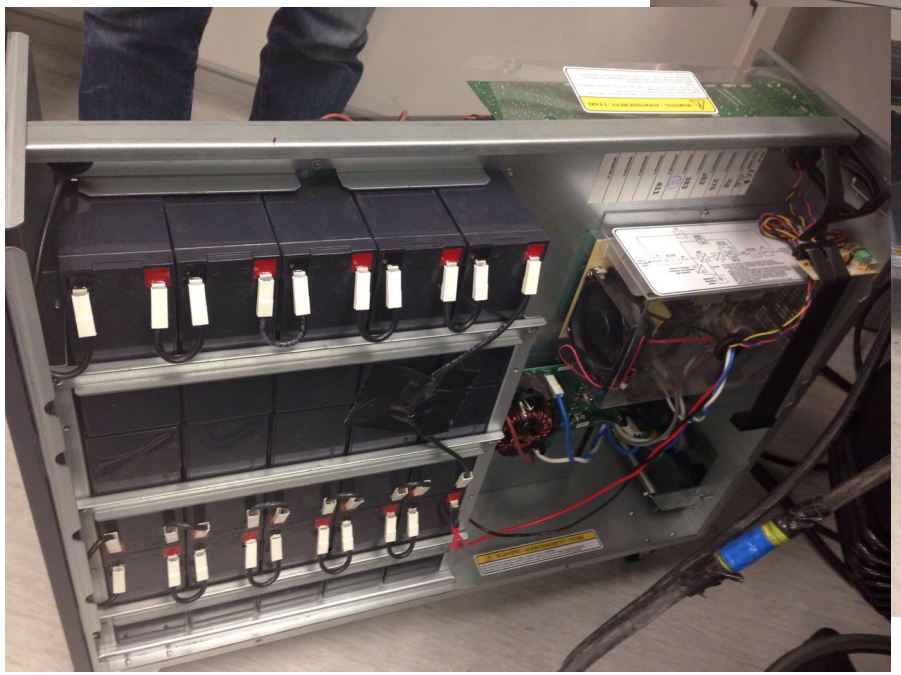
MC9S12E128 Controller Board



UPS 5KVA



12V 9Ah (20pcs)



Socomec Power Module

Output Voltage

- Pure Sine Wave and Simulated Sine Wave / Modified Sine Wave

Pure Sine Wave

Adv	DisAdv
▪ Smoother and cleaner output for sensitive equipment ▪ Improves equipment performance and efficiency	▪ Approximately two times the cost of a comparable modified sine wave UPS system

Modified Sine Wave

Adv	DisAdv
▪ Approximately half the cost of a pure sine wave UPS system	▪ Less smooth and stable output ▪ Decreased equipment performance and efficiency

Square wave
Square sine wave
Step sine wave
Module sine wave
Even sine wave
Pure sine wave
True Sine wave

Use of an Isolation Transformer for Online UPS

1. Voltage conversion

An isolation transformer can be designed as either step up or step down to convert voltages to desired levels so that the connected loads get the required voltage.

2. Reduce fault current supply to loads

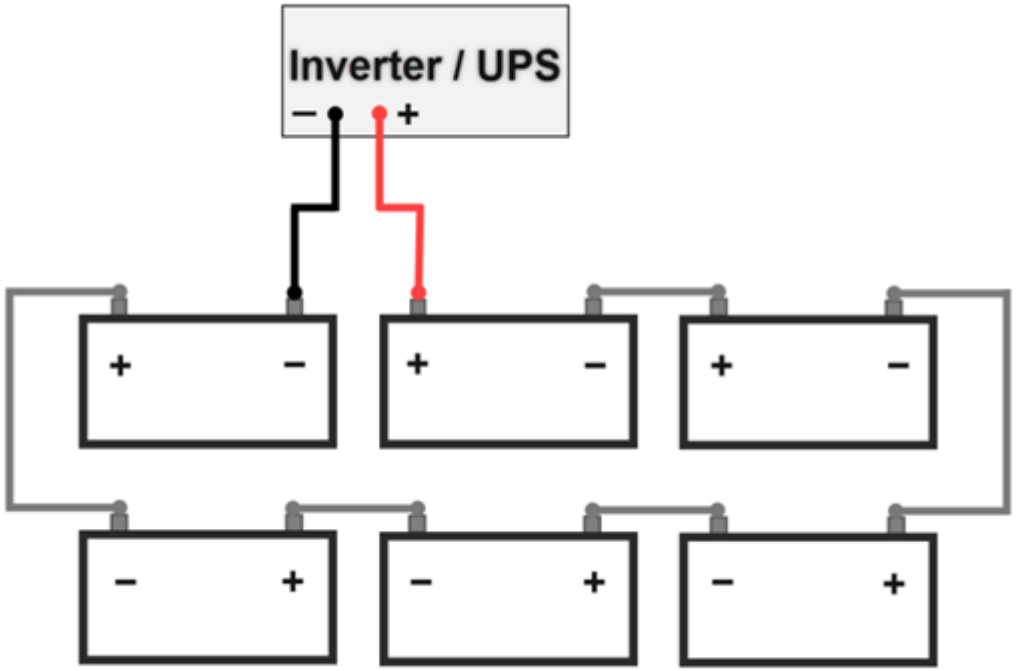
Isolation transformer helps in reducing noise and fault current thereby ensuring the proper working of connected equipment. Isolated transformers make use of Faraday shields to get rid of noise and leakage currents.

3. Easy maintenance of UPS

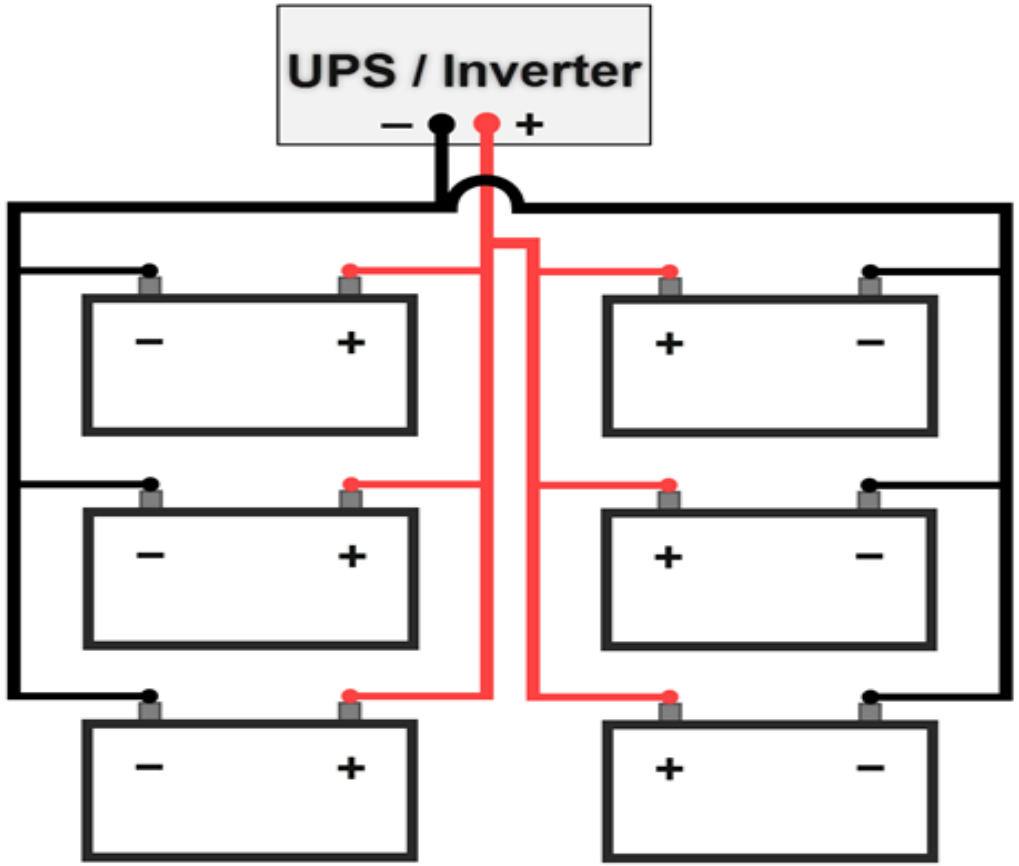
An isolation transformer kept external to UPS makes maintenance of UPS easy. Isolation of UPS from the power source prevents risks of electrical shocks during the testing or service of the UPS. Hence it ensures the safety of the technicians doing the maintenance work.

A Three-Phase Isolation Transformer

- Battery Bank Arrangement

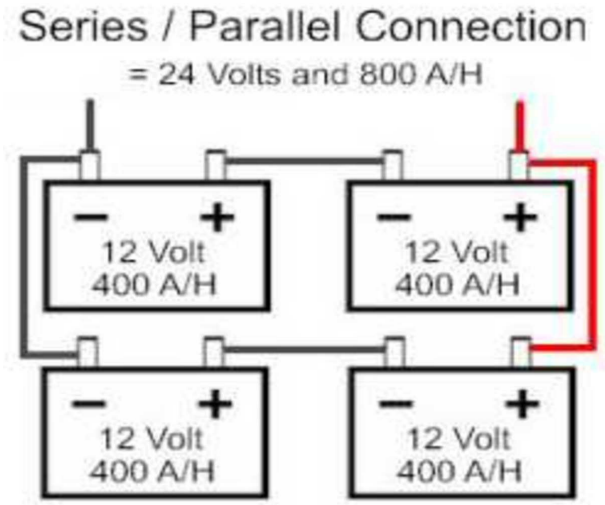


- Battery connected in series e.g. 12v, 7AH Battery=12x6=72V 7AH



- Battery connected in parallel

e.g. 12v, 7AH Battery=7Ah X 6=12V 42Ah



Capacity of Battery Bank

Formula is (Wh)*1000/(V) =(mAh).

For example, if you have a 1.5Wh battery rated at 5V, the power is 1.5Wh * 1000 / 5V = 300mAh.

Calculate UPS/inverter Battery Back-up Time?

Simple formula:

Backup Time (in hours) = Battery Capacity (in Ah) X Input voltage (V) / Total Load (in Watts)

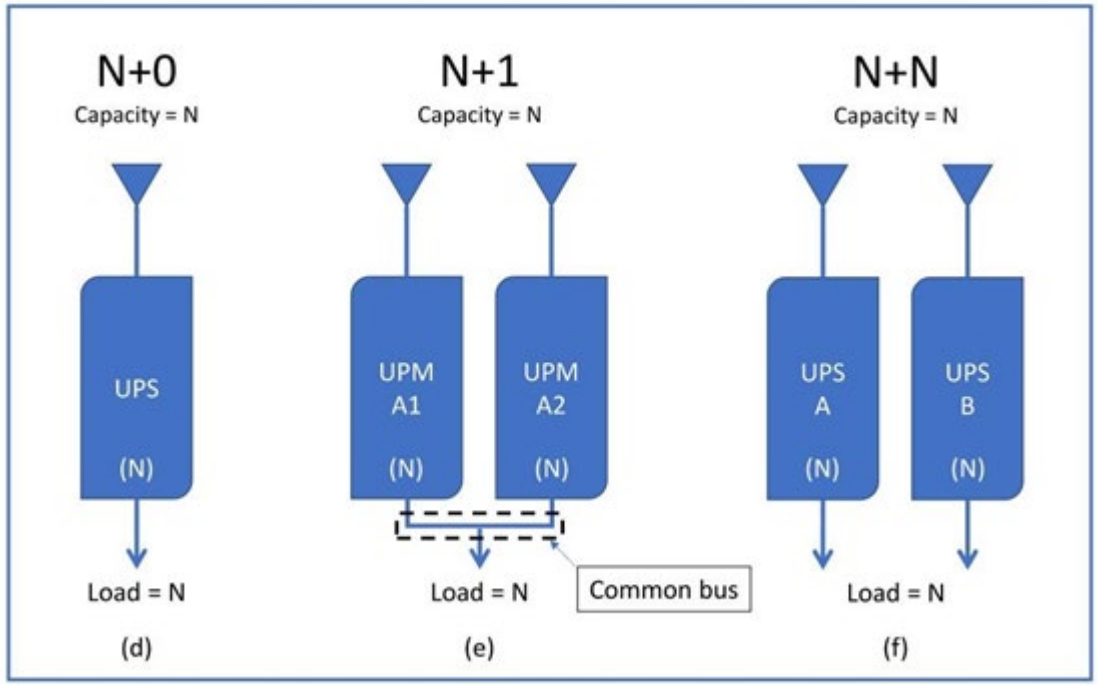
Battery Type and Features /

- ***Valve Regulated (VRLA) or*** Sealed Lead-Acid (SLA)
- this is the most common type found in modern UPS systems. They typically come with a 5 or 10-year design life and are best stored in a dry, climate-controlled room at a temperature of 20-25°C.
- sealed inside a case which has a valve that vents to release gas if internal pressure gets too much, hence the term “valve regulated”.
- Because they are sealed, they can be mounted either vertically or horizontally
- suitable for use within rackmount trays or external cabinets. They don’t need any direct maintenance such as being regularly topped up with water.

- ***Open Vented (VLA)***
- these batteries have plates that are flooded with electrolyte acid. They have a long design life (up to 20 years) and are typically used in large installations needing a high ampere-hour (Ah) rating.
- hydrogen generated escapes directly into the environment. This means installations using VLA batteries require more powerful ventilation systems and can pose a greater safety hazard.
- VLA batteries must be placed in a dedicated room with wash-down facilities in case of acid leaks. Because they are top-vented, they must also be kept upright, with the water levels manually topped up.

- **Lithium-Ion UPS Batteries**
- higher reliability than VRLA/SLA batteries because of built-in battery monitoring and management systems, which check every individual cell.
- they are significantly smaller and lighter because of their significantly higher power density. They also have faster charge times, longer cycles, and at least double the service life compared to VRLA/SLA.
- generates less heat and can operate at higher temperatures, meaning they don’t require as much air conditioning, which can reduce cooling costs.
- far more expensive initial choice than the other options.

6. UPS Redundancy



Non-Redundant, N+0

Figure (f) shows a single UPS system which provided the means to bridge the gap for when utility power failed, and a generator started and powered the UPS and its critical load. This was a non-redundant UPS design. It met the basic requirement of protecting the load from utility issues and little more. If the UPS failed, the load was dropped.

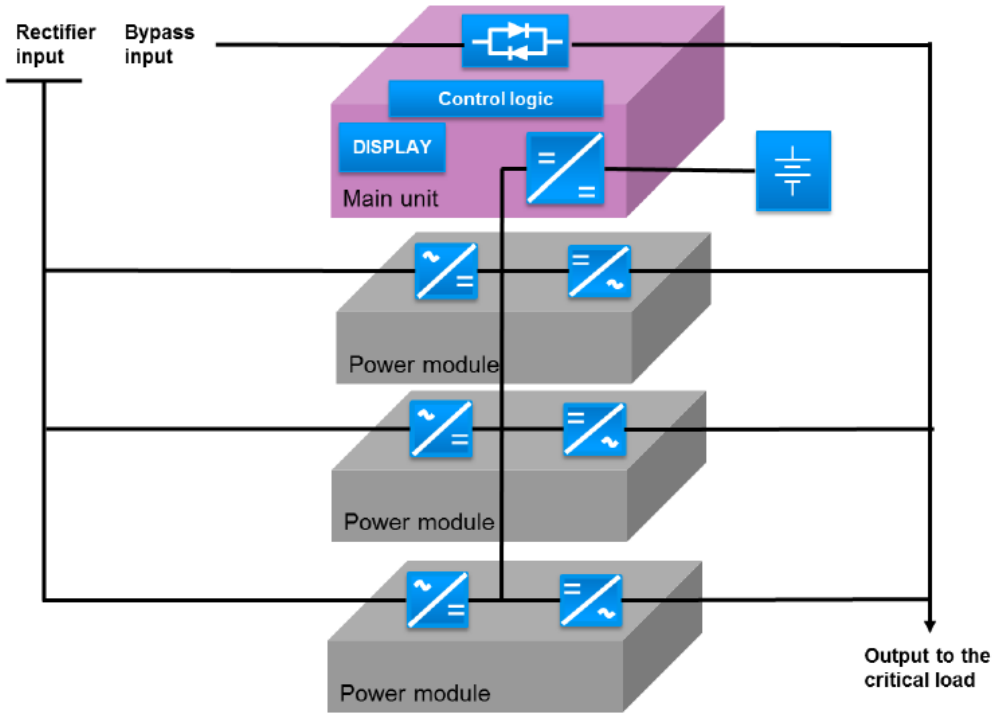
Module Redundancy, N+1

Figure (e) shows a N+1 redundant UPS system. In this arrangement a single UPS system, comprised of two parallel modules, connected to a common system output, powers all the load. Each module is rated for N capacity and share the load. If the load remains at or below N, the system is redundant. The '+1' indicates there is one more module than needed to power the load. However, if the load increases above N, the system will be non-redundant.

System Redundancy, N+N or 2N

Figure (f) shows a typical redundant design for UPS systems that power IT equipment with dual corded power supplies. In this arrangement there are two UPS systems, each system is comprised of one module with N capacity.

Modular UPS (Gen 1) – Centralized design

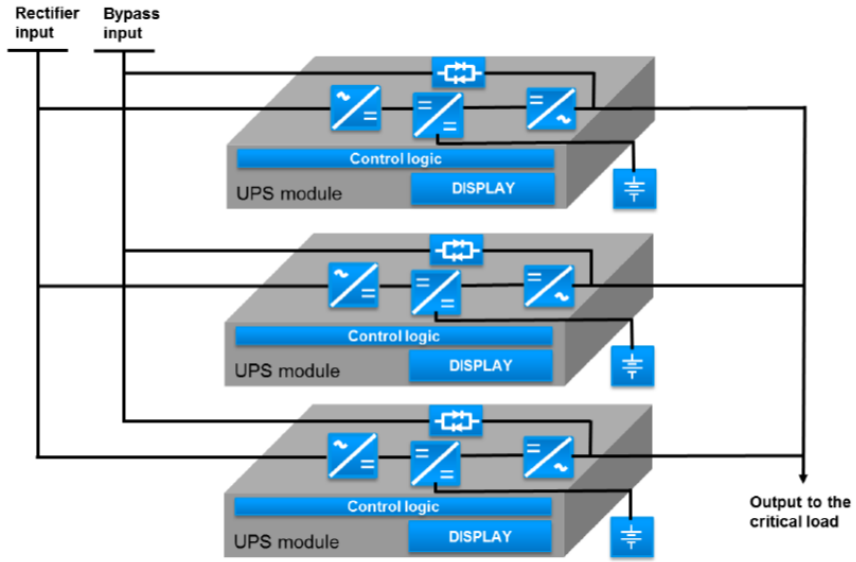


Centralized Modular UPS

- Traditional modular UPS design
- All control logic, static switch etc., centralized in UPS frame
- UPS frame is system control cabinet (SCC)
- Several single points of failure

Evolution of Modular UPS (Gen 2)

Decentralized Parallel Architecture (DPA)

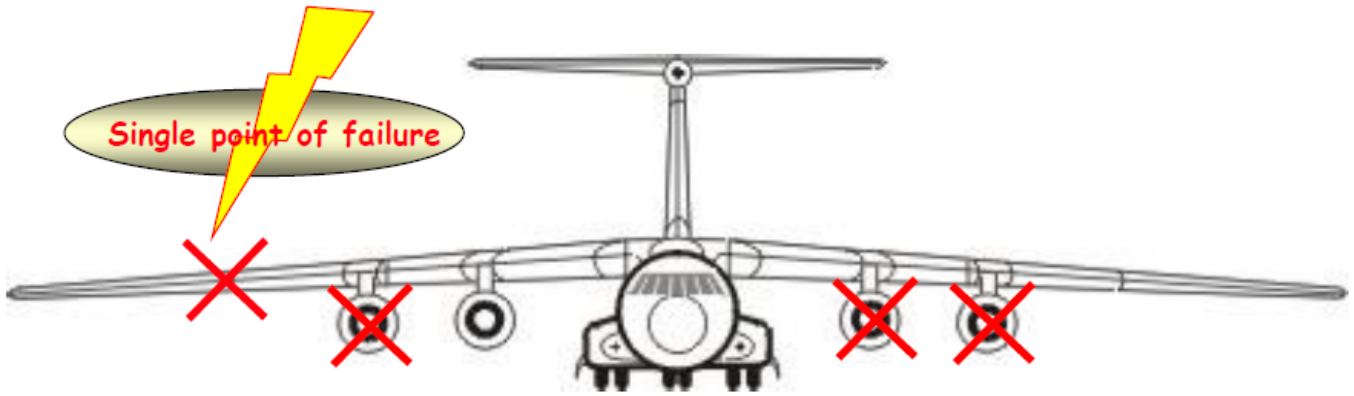


Decentralized Modular UPS

- All control logic, static switch etc., in each power module
- Power module is a complete UPS
- Passive frame design
- High availability
- Eliminates single points of failure
- Perfect load sharing
- Any UPS can be the logic leader (multi-master system)

ABB - Advances in Modular UPS

All about redundancy – eliminate single point of failure

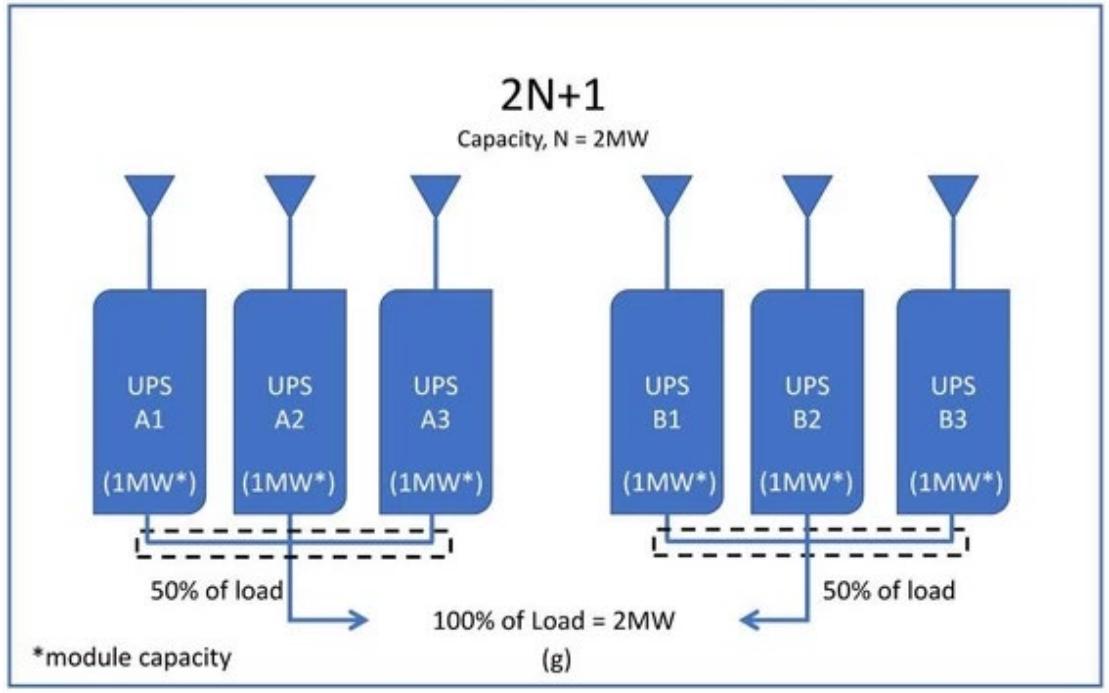


If the demanded function is fly, redundancy means:

- Three (3) engines can fail, and the demanded function is maintained
  REDUNDANCY N+3
- If one wing fails, the demanded function is not maintained
  NO REDUNDANCY

Redundant Systems with Redundant Modules, 2N+1

Higher levels of redundancy can be achieved by using two N+1 UPS systems as shown in Figure (g).This is sometimes referred to as 2N+1. This system design can withstand a complete system failure and one module failure and still deliver full UPS capacity. This design is very costly and mostly used by financial companies or the highest mission critical installations.

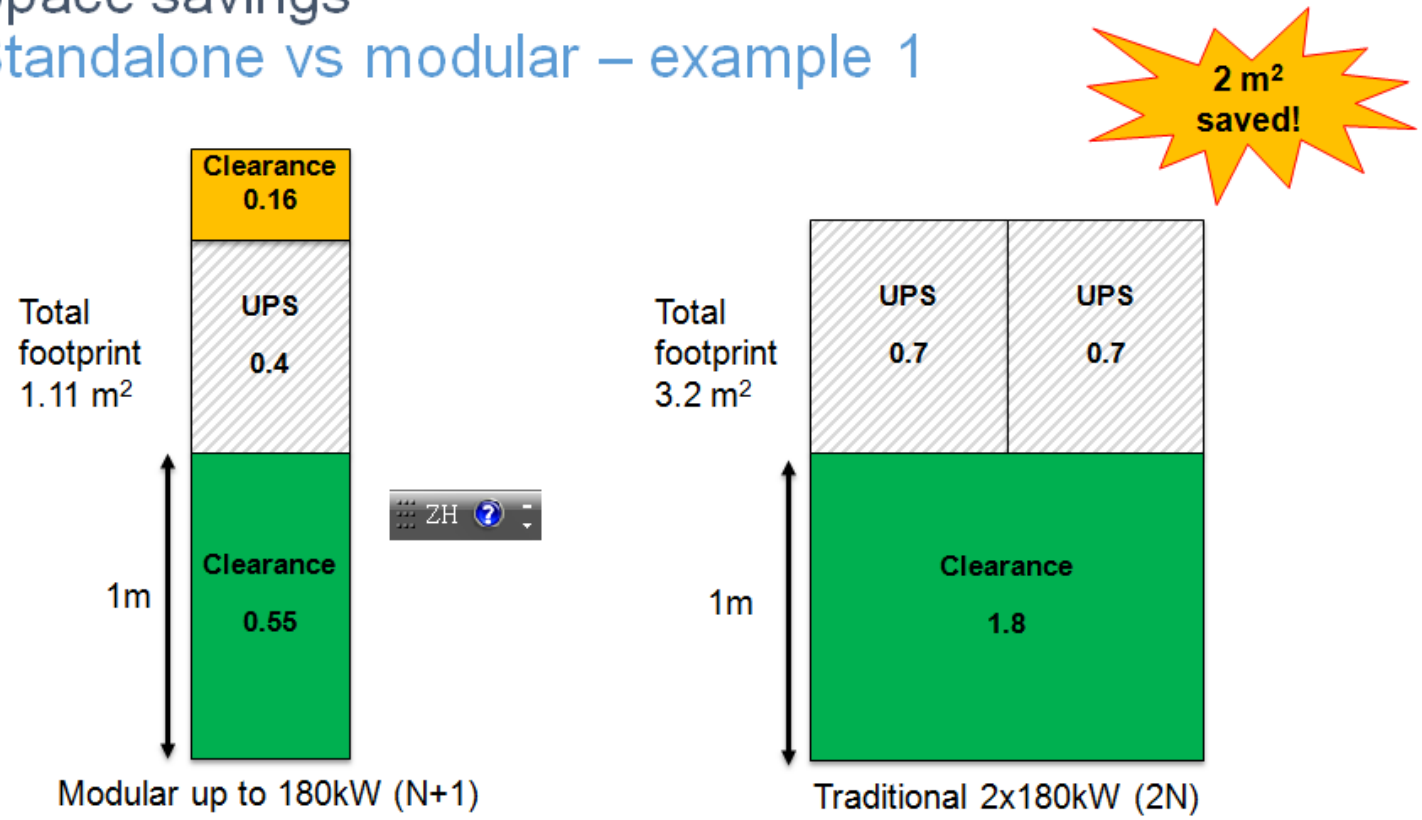


Comparing UPS
n Design Configu

Redundancy	Redundant Capacity	Number of 1MW Modules	Installed Capacity	Maximum Module Utilization	Maximum System Utilization
N+0	Not redundant	2	2MW	100%	100%
N+1	2MW	3	3MW	67%	67%
N+N	2MW	4	4MW	50%	50%
2N+1	2MW	6	6MW	33%	50%

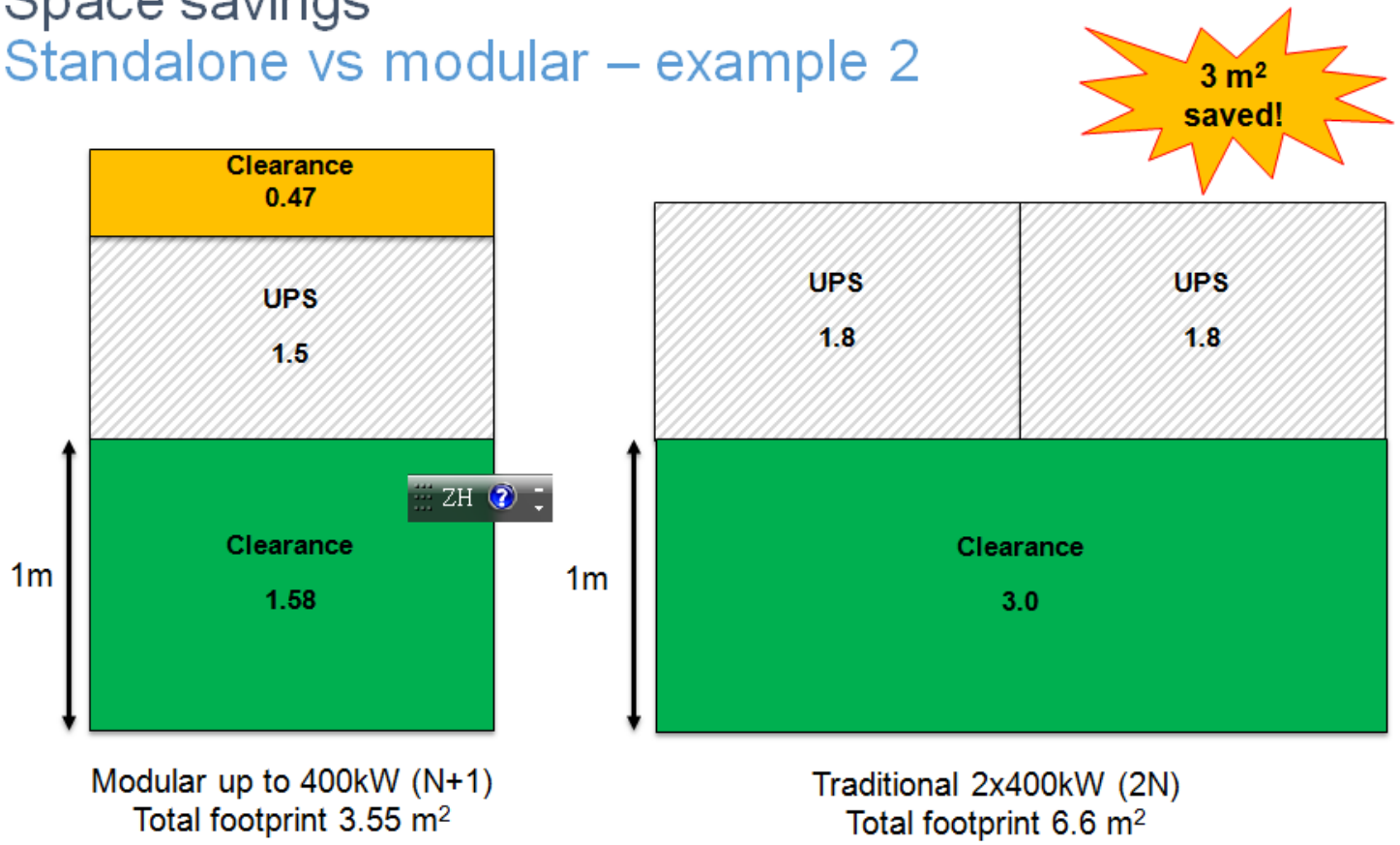
Table 1

Space savings
Standalone vs modular – example 1



Modular UPS are concurrently compact and redundant !

Space savings
Standalone vs modular – example 2



Modular up to 400kW (N+1)
Total footprint 3.55 m²

Traditional 2x400kW (2N)
Total footprint 6.6 m²

5. Associated System

- Automatic transfer switches (ATS)

is a device that automatically transfers a power supply from its primary source to a backup source when it senses a failure or outage in the primary source.

- Battery Monitoring System (BMS)

Remote monitoring the battery by Wire or Wireless

To monitor the impedance of the different battery mono blocks

- Central Control and Monitoring Systems (CCMS)

Remote monitoring the UPS operation and alarms (e.g. Battery Discharge, Bypass)

7. System Design Considerations

- Backup Time at Full Load (customized by user)
- Power environment: single and three-phase
- Redundant UPS, generator and two power.
- Floor loading assessment (battery bank and isolation transformer)
- Ventilations and 7x24 air-conditioned environment
- Operation and maintenance
- Check to see if there’s an adequate electrical supply near the UPS.
- Find out the dimensions of the UPS and include any battery cabinets.
- Verify the UPS solution meets local building codes. (e.g FS regulation)
- Alarm system (central or local, fire, flooding)
- Budget

- Departmental Reference:
- General Requirements for Uninterruptible Power Supply (ESG15_Issue7)
- Uninterruptible Power Supply (UPS) Maintenance Policy Health Sector Division (HSD) Electrical & Mechanical Services Department

8. Risk Assessment: Report

Risk Matrix

Likelihood / Severity	Likely /Frequent	Probable	Possible	Remote	Improbable
Catastrophic	Extreme	High	High	Moderate	Low
Major	High	High	Moderate	Moderate	Low
Minor	High	Moderate	Moderate	Low	Low
Insignificant	Moderate	Low	Low	Low	Low

Likelihood

Likely/Frequent (Li)	Occurs repeatedly/event only to be expected
Probable (Pr)	Not surprised, will occur several times
Possible (Po)	Could occur sometime
Remote (Re)	Unlikely, though conceivable
Improbable (Im)	So unlikely that probability is close to zero

Severity

Catastrophic (Ca)	Result in multiple fatalities or extensive outbreak of human infectious diseases
Major (Ma)	Result in fatality or major/extensive injuries or Occupational Diseases which require long period of medical treatment
Minor (Mi)	Result in minor injuries or ill health which could be recovery within a short period of time
Insignificant (Im)	Result in no injury or only first aid treatment required

Actions are recommended for each of the risk level tracked from the risk matrix

Extreme (E)	The activity should not be preceded. The working method should be re-designed and re-assessed.
High (H)	The activity should not be proceeded unless appropriate risk control measure are in place. The control measure should be implemented within one month after the assessment. Temporary safety measure should be adopted.
Moderate (M)	Consider whether further reasonably practicable action is available to eliminate or reduce the risk. Monitoring is required to ensure that the existing controls are maintained effectively and safety working procedures are followed.
Low (L)	Acceptable risk, no additional control measure is needed but monitoring is required to ensure that the existing controls are maintained effectively and safety working procedures are followed.

Battery Guide Line

Risk Assessment Report

xxx

Work Activity /Operation: Maintenance and Acceptance of UPS

Date of Assessment: xxx

Report no.: RA-15-BES13(0)

Assessed by: xxx

Location: User Premises / Hospital Workshop

Reviewed by: xxx

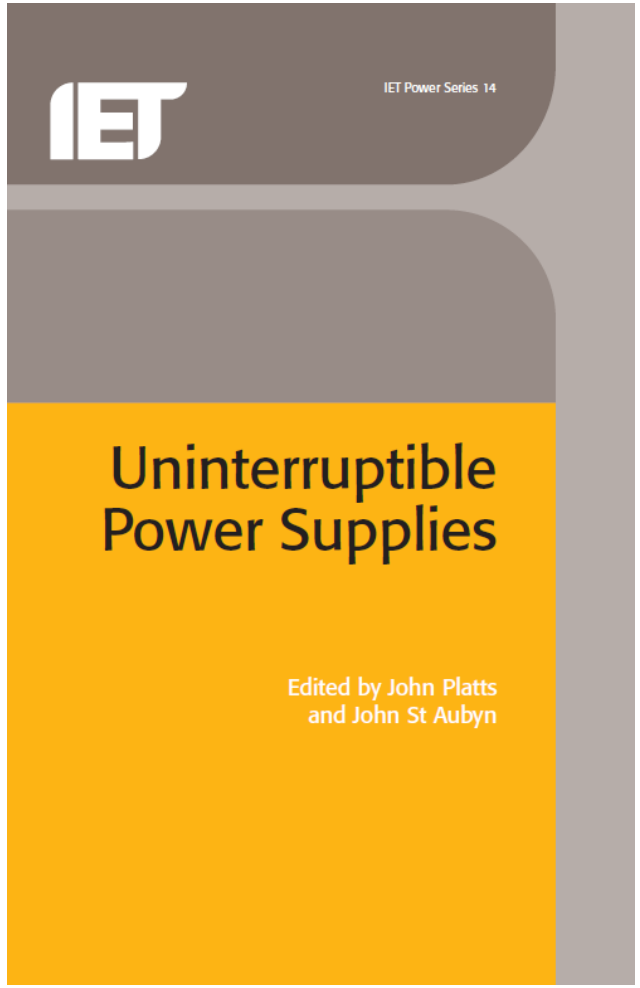
Item 項目	Tasks 工作活動	Hazard 危害	People Affected 受影響人士	Existing Control Measure 現有控制措施	Likeli-hood 機率	Conse-quences 後果	Risk Level 風險等級	Additional Control Measures 附加控制措施	Residual Risk 風險等級	Action by 執行
1.	Electrical work.	Electrical hazard.	Servicing staff.	- Disconnect electricity during the assembly and disassembly processes. - Follow the tagout procedures.	Im.	Ca.	L.	-Disconnect electricity should be conducted by electrician. - Thoroughly implemented lockout and tag out proof dead" and "point to point proof dead". -Keep the key and displayed the contact number.	L	電工/主管
2.	Manual handling.	Physical hazard.	Servicing staff.	- Use equipment with trolley to minimize manual handling. - Use trolley to assist transportation, minimize the duration of manual handling. - Work in pairs or in groups when handling heavy components. - Refer to the safety guidelines as stated in OHSI 19.	Re.	Mi.	L.	-Manual Handling Risk assessment should be conducted -Make sure your physical in good condition.	L	工人/主管
3.	Use of Chemicals .	Chemical hazard.	Servicing staff.	- Wear suitable PPE such as protective clothing, gloves, goggles & respirator. - Keep relevant MSDS & chemicals assessment reports in site office for reference. - Refer to the safety guidelines as stated in OHSI 17.	Re.	Mi.	L.	-Fully understanding MSDS requirement/information	L	工人/主管

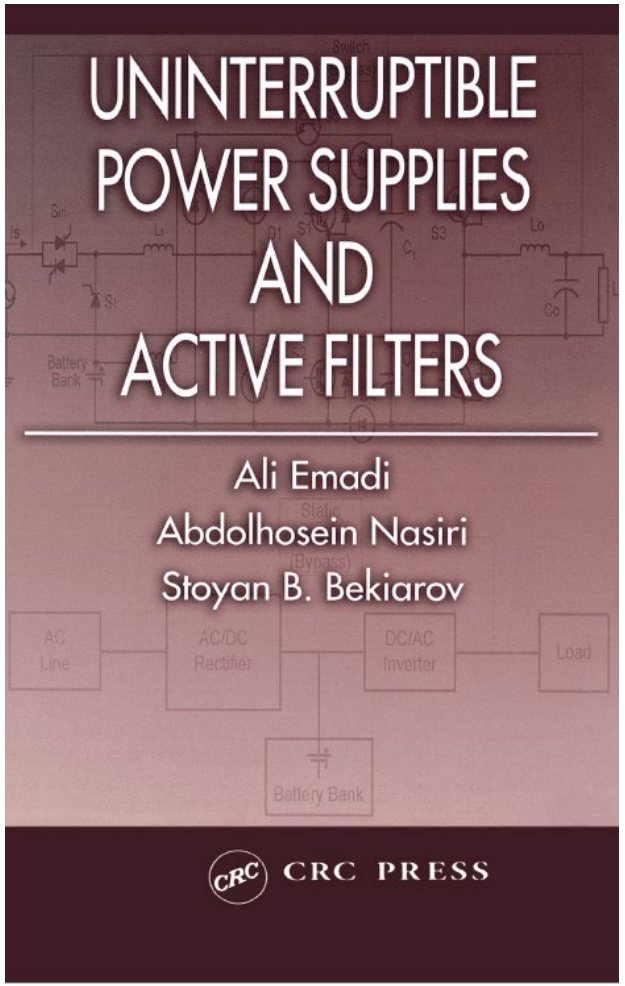
Risk Assessment Report

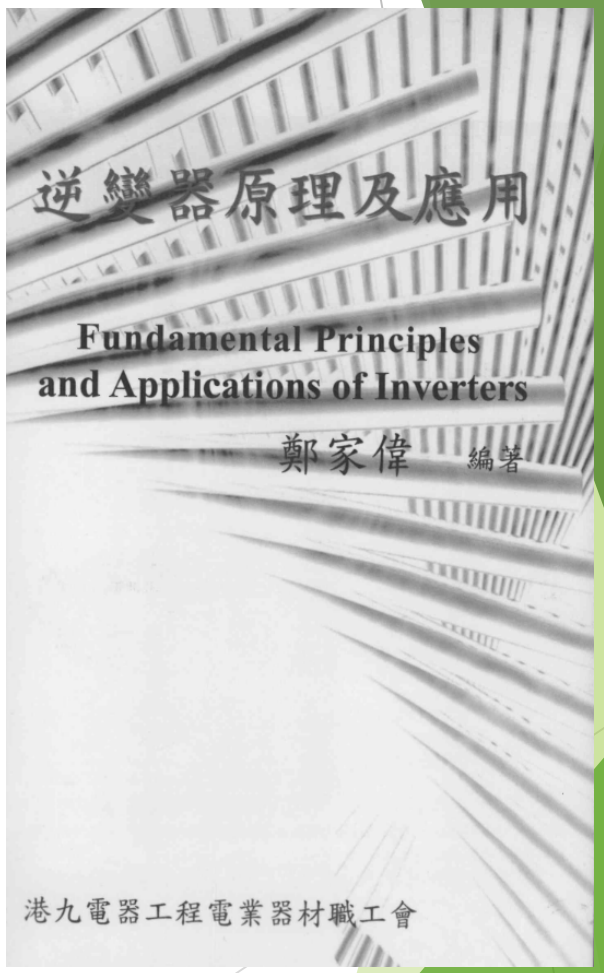
xxx

Item 項目	Tasks 工作活動	Hazard 危害	People Affected 受影響人士	Existing Control Measure 現有控制措施	Likelihood 機率	Consequences 後果	Risk Level 風險等級	Additional Control Measures 附加控制措施	Residual Risk 風險等級	Action by 執行
4.	Battery test Battery disposal Excessive explosive gases accumulated inside the battery room.	Fire & explosion.	Servicing staff	- Place suitable fire fighting equipment in the working area or near the working area. - Display clearly the fire escape route or exit within the workshop. - Provide briefing or training on fire safety to staff. - Refer to the safety guidelines as stated in OHSI 03. - Provide ventilation.	Re.	Ca.	M.	-Emergency escape layout plan should be displaced. -No naked fire and smoking at workplace.	L	工人/主管
5.	Working in high risk (infectious hazard) areas. Contact with contaminated equipment including the cleaning process.	Infectious hazard.	Servicing staff.	- Follow the system of disinfection before maintenance to ensure the disinfection status of the equipment before carrying out the maintenance service. - Provide adequate PPE to staff. - Refer to the safety guidelines as stated in OHSI 37. - Observe the infection control measures from hospital or client.	Re.	Ca.	M.	Ensure the PPE properly worn and check by partner.	L.	工人/主管

Reference







END of PART 1