Lecture # 2

ECEN 438/738 Power Electronics

Spring 2025 Semester

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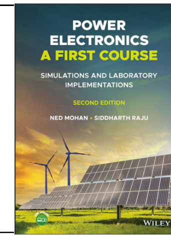
ECEN 438/738 Power Electronics



Power Electronics
A First Course: 2nd Edition

Free Textbook Online Access Link: https://go.oreilly.com/TAMU/library/view/-/9781119818564/?ar

Chapter 1
Power Electronics: An Enabling Technology

ECEN 438/738 Power Electronics

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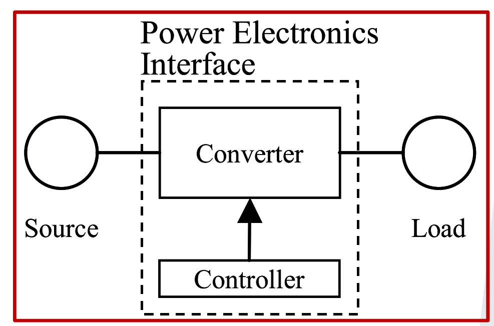
Introduction to Power Electronics

- Role
- Applications
- Requirements

Role



Applications

- Portable Electronics
- Consumer Electronics / Appliances
- Renewables-based Electricity Generation
- Electric/Hybrid Vehicles
- Improving Efficiency
- Utility Applications
- Information Technology

Applications: Renewable Energy -Solar PV

Residential

Space

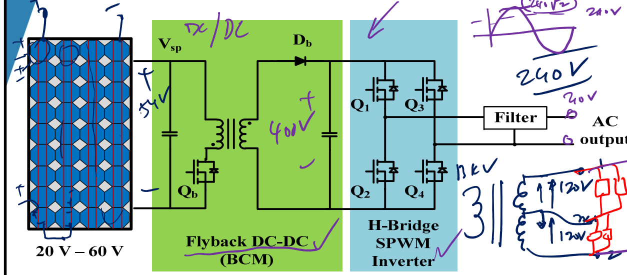
Commercial

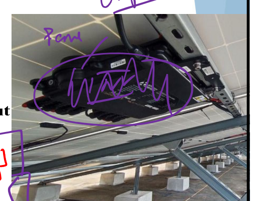
Public

Utility Scale

Agriculture

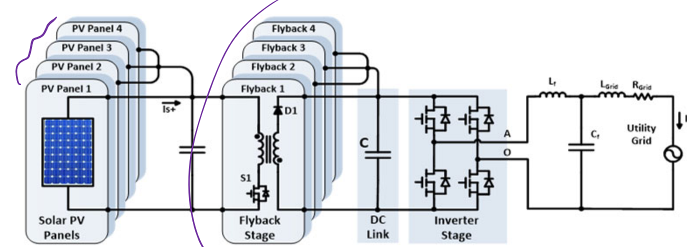
PV Microinverter with a Flyback DC-DC and DC-AC Inverter





- A flyback DC/DC converter with HF isolation & a H-Bridge PWM inverter offers a simple two stage solution
- Mounted behind the PV panel and outputs ac voltage - plug and play convenience

One Microinverter for 4 Solar Panels



- Another common configuration of micro-inverter.
- Four PV panels are used to reduce microinverter cost per panel
- Four Flyback converters in parallel to achieve Maximum Power Point for each panel.

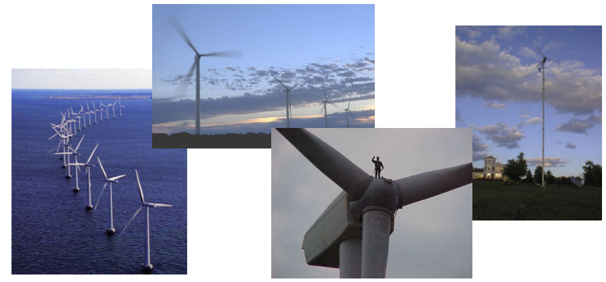
Commercial Product

- Hoymiles 4 in 1 Micro-inverter

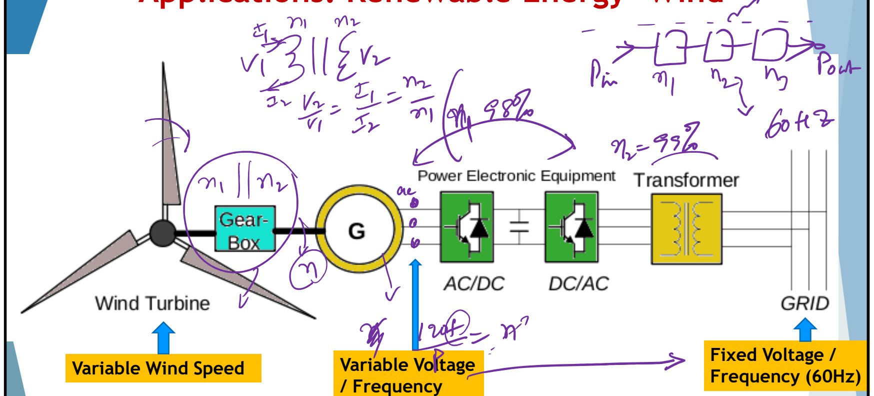
Model	MI-1000 / MI-1200 (4X60 cells / 4X72 cells)		
Input Data(DC)			
Recommended input power (W)	Up to 1240 / 1520		
Peak power MPPT voltage range (V)	27 ~ 48 / 32 ~ 48		
Start-up voltage(V)	22		
Operating voltage range (V)	16 ~ 60		
Maximum input voltage (V)	60		
Maximum input current (A)	10.5		
Output Data (AC)	@208V AC	@240V AC	@230V AC
Rated output power (W)	000 / 1200	1000 / 1200	1000 / 1200
Rated output current (A)	4.81 / 5.76	4.16 / 5	4.35 / 5.22
Nominal output voltage/range (V)	08/183-250	240 / 211-264	230/180-275
Nominal frequency/range (Hz)	0/59.3-60.5	60 / 59.3-60.5	50/45-55
Power factor	> 0.99	> 0.99	> 0.99
Output current harmonic distortion	< 3%	< 3%	< 3%
Maximum units per 20A branch	3 / 3	4 / 3	4 / 3
Efficiency			
CEC peak efficiency	96.50%		
CEC weighted efficiency	96.00%		
Nominal MPPT efficiency	99.80%		
Night time power consumption (mW)	<50		

Applications: Renewable Energy -Wind

Wind Turbines:
Power for a House or City



Applications: Renewable Energy -Wind



Efficiency Improvement Lighting

No Power Electronics

100 W

8hrs a day for 365 days
= 100*8*365 = 292 kWh
If 1 kWh = 10 cents
Then electricity cost is
= $29.2

Power Electronics High frequency converter

23 W

8hrs a day for 365 days
= 23*8*365 = 67.16 kWh
If 1 kWh = 10 cents
Then electricity cost is
= $6.72

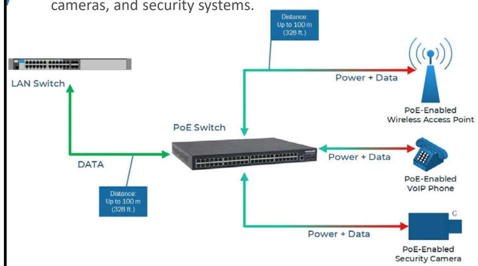
LED

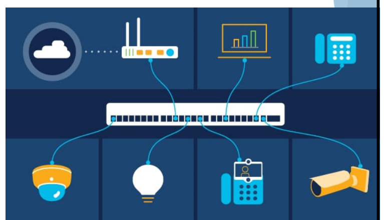
17 W

8hrs a day for 365 days
= 17*8*365 = 49.74 kWh
If 1 kWh = 10 cents
Then electricity cost is
= $4.97

Power Over Ethernet (PoE) ?

- **PoE refers to the ability to provide low-voltage (less than 100W), direct current (DC) electrical power to network devices via the same twisted-pair copper Ethernet cables that are used to transmit data. This eliminates the need for a separate AC power source and allows for more flexible placement options, without concern for proximity to a power outlet.**
- PoE is a low-cost, reliable, and flexible approach to powering smart devices in a network. It is crucial to enabling smart buildings and their ecosystems of network-connected devices such as lighting, window shades, sensors, HVAC controllers, cameras, and security systems.

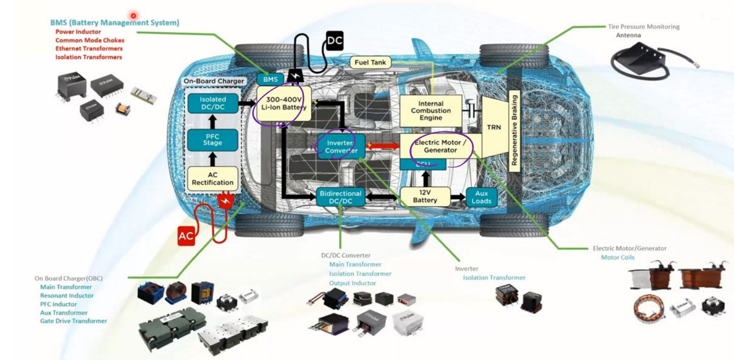




Benefits: https://www.cisco.com/c/en/us/solutions/enterprise-networks/what-is-poe-lighting.html

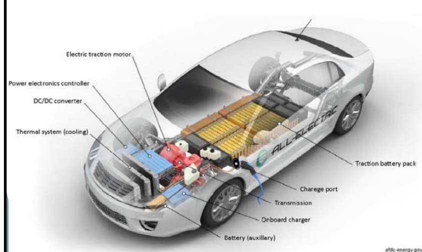
Automotive Power Electronics

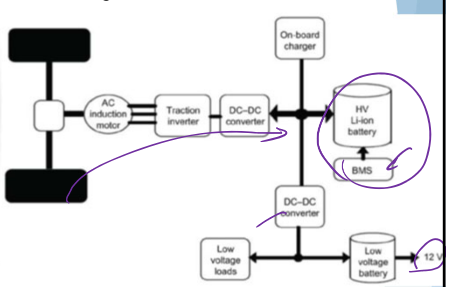
Automotive Power Train



Typical Electric Vehicle

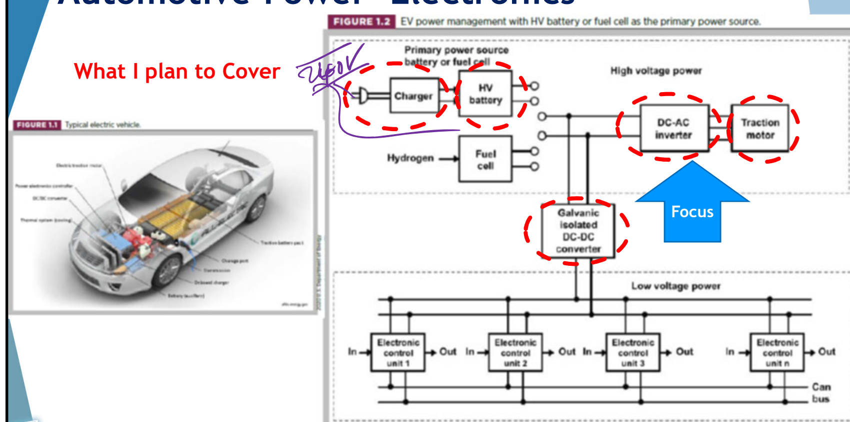
- EV is powered by either Li-ion Battery or fuel cell
- HV battery can by charged with AC powerline
- Primary DC bus provides 200-800 V
- DC-AC inverter controls the traction motor
- An isolated DC-DC converter scales down voltage for low voltage electronics





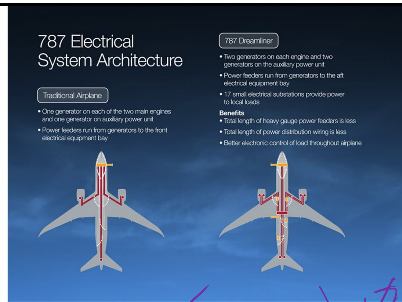
Automotive Power Electronics

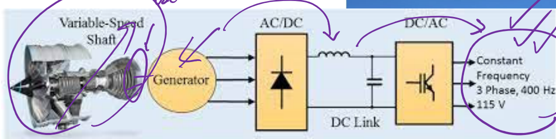
What I plan to Cover



Aircraft Electrical Power

400 Hz
Variable Speed Constant Frequency (VSCF)



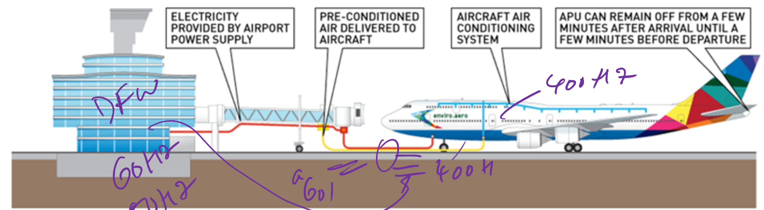


n_1
n_2
n_3
η

https://passive-components.eu/electrical-equipment-evolution-in-civil-aeronautics-handling-high-power-up-to-1000kw-from-the-designer-point-of-view/

Aircraft Ground Electrical Power

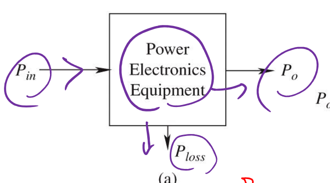
50/60 Hz (airport power) to 400 Hz Converter

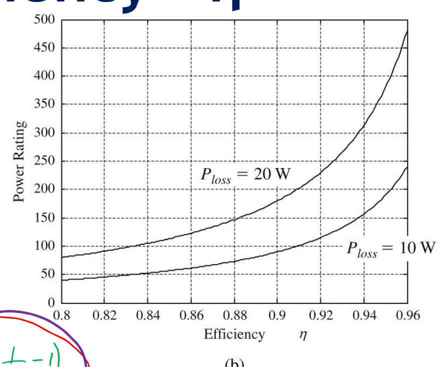


DFW
60Hz
50Hz
60 = 400 Hz
400 Hz

Efficiency - η

$P_{in} = P_o + P_{loss}$





$$\eta = \frac{P_o}{P_{in}} = \frac{P_o}{P_o + P_{loss}}$$

$$P_{loss} = P_{in} - P_o \Rightarrow \frac{P_o}{\eta} - P_o \Rightarrow P_o\left(\frac{1}{\eta} - 1\right)$$

Figure 1.14

Efficiency - η

If the output power is still 100 Watts, Designer B can achieve 11 time smaller size than Designer A

A power supply draws power from the utility input (Pin) and is designed by designer **A** to deliver an output power Po = 100 Watts to a load at 90% efficiency.

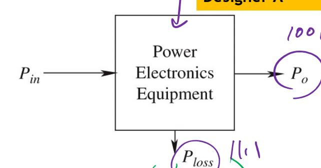
a) Calculate the losses

$P_{loss} = P_o\left(\frac{1}{\eta} - 1\right) = 100\left(\frac{1}{0.9} - 1\right) = 11.1$ watts

Now Another designer **B** employs the same package size and with advanced semiconductor devices / power electronic circuits is able to achieve an efficiency of 99%

what is the maximum output power that can be supplied to output load using the same package?

Note: Since the size of the package in both cases is the same, assume that the maximum allowed power dissipation within this power supply, without overheating it, remains unchanged.



100 W

11.1

$P_{loss} = 11.1 = P_o\left(\frac{1}{0.99} - 1\right)$

$\boxed{P_o = 1100 \text{ watts}}$

11 times more power

High efficiency is essential

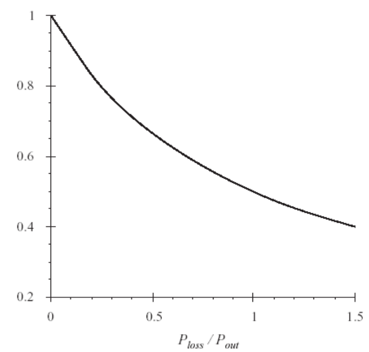
$$\eta = \frac{P_{out}}{P_{in}}$$

$$P_{loss} = P_{in} - P_{out} = P_{out}\left(\frac{1}{\eta} - 1\right)$$

High efficiency leads to low power loss within converter

Small size and reliable operation is then feasible

Efficiency is a good measure of converter performance



Class Attendance Log: 1/16/25

MOSFET

Efficiency - η

The 90s

Today

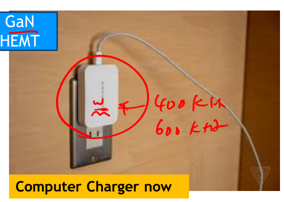
90V to 265V (50/60 Hz))

Silicon MOSFET

19.5 V

Computer Charger then

GaN HEMT



Computer Charger now

ac – dc – dc-dc

400 kHz

600 kHz

Laptop - Power Management

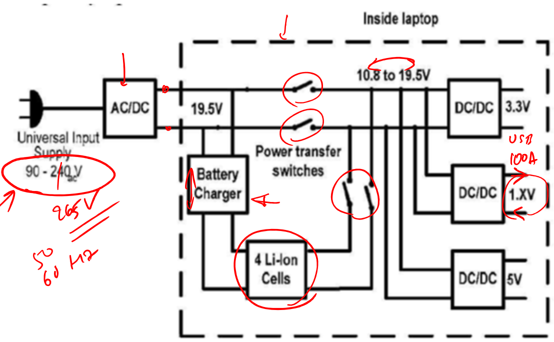
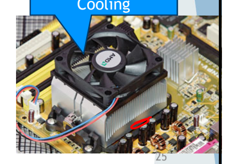


Figure 2: Conventional laptop power management architecture

Heat pipes inside a gaming laptop for cooling

Microprocessor Cooling



Applications

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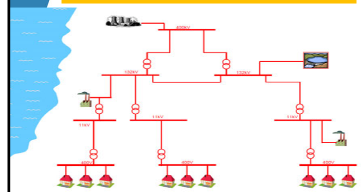
Todays – Electric Utility



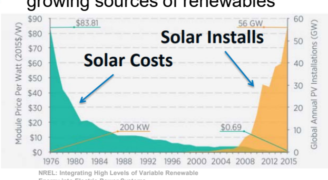
Today we have a radial power distribution system with 3 major objectives:

1. Improve reliability i.e. faults are isolated rapidly
2. Minimize the delivery losses (not paid by the customer)
3. Deliver high quality electricity - especially voltage magnitude

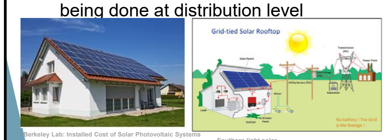
- These objectives are typically achieved via distribution management systems (DMS). One of the function of DMS is FISR, fault isolation and service restoration. FISR controls the opening and closing of circuit breaker to increase reliability.
- The other function of DMS is VVC, volt var control. VVC controls voltage control devices, such as load tap changer, voltage regulators and capacitors bank to minimize the delivery losses while maintaining a good voltage profile along feeders.

Renewables on the Rise

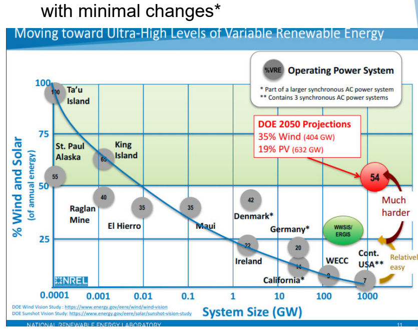
- Solar PV generation is one of the fastest growing sources of renewables



- Majority of new solar installations are being done at distribution level



- 30% renewable energy penetration is possible with minimal changes*

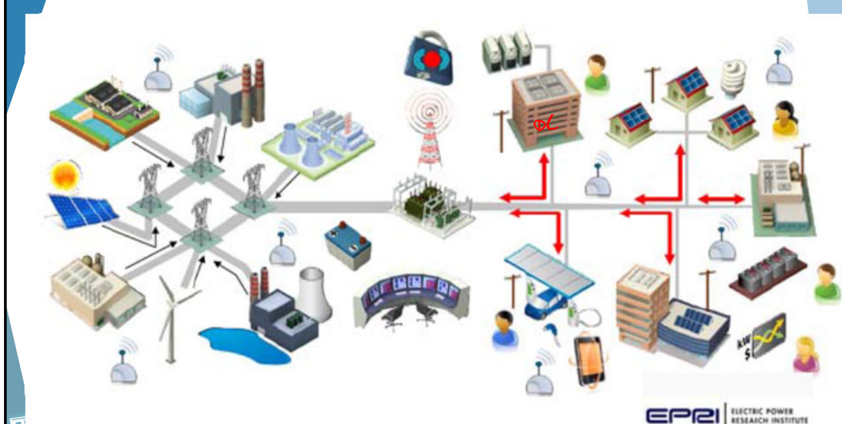


What is needed for higher levels of penetration?

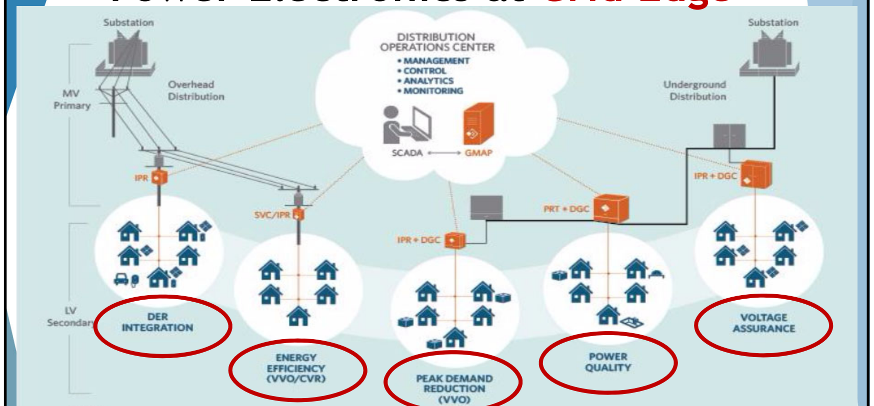
* NREL Power Systems Engineering Center

Dynamic Impact of Power Electronics Intelligence at the grid edge • Jorge Ramos

Tomorrow - Increased Renewable Energy Integration



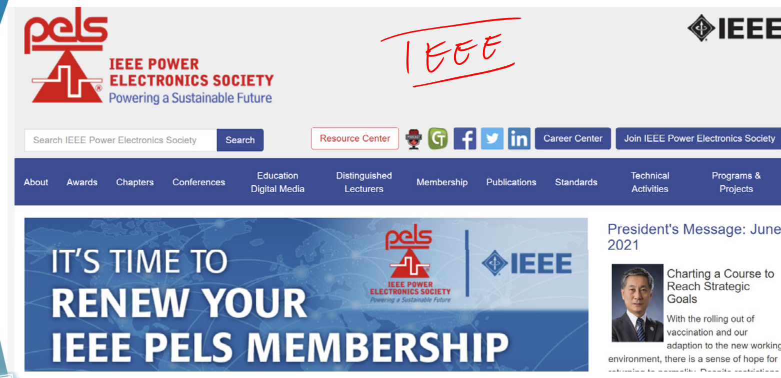
Power Electronics at Grid Edge



Technology for the Grid of the Future - as smart at the internet

IEEE Power Electronics Society

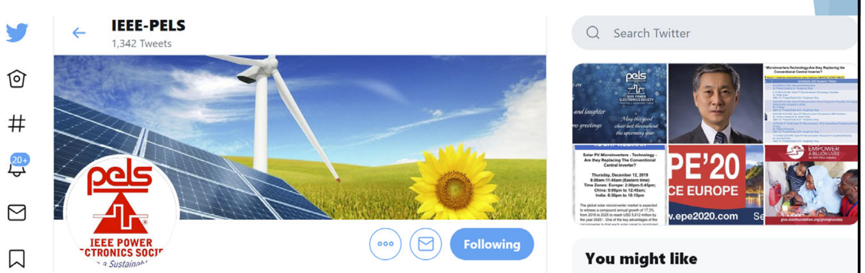
http://www.ieee-pels.org



Twitter

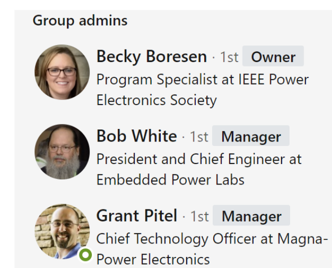
IEEE Power Electronics Society

https://twitter.com/IEEEPELS



IEEE Power Electronics Society

https://www.linkedin.com/groups/2091456/



Quiz # 1 - Due Jan 18th (midnight)
Available on CANVAS
4 attempts to score 100

Please discuss the quiz in TEAMS channel