CPAP and medical artificial ventilators
Disclaimer for critical applications

- Product(s) indicated in this presentation are sold under ST terms and conditions and they are not designed, intended or authorized for use as a critical component in life support systems, or any FDA Class 3 medical devices or medical devices with a similar or equivalent classification in a foreign jurisdiction, or any devices intended for implantation in the human body.

- Contact ST Sales Offices for any further details.
Continuous Positive Airway Pressure (CPAP) helps patients breathe by holding open the alveoli and preventing them from completely collapsing during expiration phases.

The most important aspect in a CPAP system is the air flow control that needs to be adjusted to compensate for altitude, mask movements, and leaks as well as features including heated, humidified, airway respiratory support.

Normally, CPAP is suitable for use in institutional, home, and portable settings. It is not intended for use in Emergency Medical Service (EMS) such as an emergency transport.

Medical artificial ventilators are machines supporting patient breath by providing mechanical ventilation by pushing air into and out of the lungs, to supply breaths to a patient who is tangibly unable to breathe or breathing insufficiently.

Modern ventilators are computerized controlled machines, mainly used in Intensive Care Unit (ICU), in Emergency Medical Service (as standalone units) and in Anesthesiology (as a component of an anesthesia machine).
Block diagram - Ventilators

- Enhance application safety
- Sense the injected air flow
- Drive pumps and valves
- Commands & display
- Perform precise motor control algorithms

1. Sense the injected air flow
2. Drive pumps and valves
3. Enhance application safety
4. Commands & display
5. Perform precise motor control algorithms
Patient monitoring equipment provides medical staff with the means to continuously observe a patient’s vital signs, such as the heart’s electrical activity (with an electrocardiogram), over an extended period.

They come in a variety of designs including bed-side monitors for hospital use and portable devices for home use.

In Intensive Care Unit (ICU) they become life sustain devices including a series of on-fly checks which alerts the medical staff in case of anomalies in the patient vital signs.
Block diagram – Patient monitoring

- **Read and monitor**
  - Vital Signals
  - Temperature Sensor
  - Signal Conditioning
  - ADC
  - Front End
  - MCU
  - Display Backlight
  - ESD Protection
  - Key Buttons
  - Emergency Call Button
  - Touchscreen
  - LED
  - User Interface
  - Audio Amplifier
  - Touchless Control

- **Protect patient**
  - Battery Charger
  - Digital Power Supply
  - Fuel Gauge
  - E-fuse
  - AC/DC (Switching Regulator Controller)
  - Overvoltage protection
  - Isolated Power Supply
  - Main AC: 110/230V

- **Connect and alert medical staff**
  - Powered Patient Bed
  - Ethernet
  - Ethernet Protection
  - RS232 / CAN
  - LED
  - Wireless Connectivity

- **Show patient vital signs**
  - Connect and alert medical staff
  - Protect patient
  - Read and monitor

---

6
ST offer in healthcare
CPAP and medical artificial ventilators
ST product offering for healthcare

ST is a trusted provider of high-quality technical solutions enabling the development of breakthrough medical systems

**Acquiring data**
- Sensors for Imaging
- MEMS* & measurement ICs
- Electronic interfacing

**Processing data**
- Powerful microcontrollers
- Artificial Intelligence at the edge
- Specially developed devices

**Motion Control**
- Precise and reliable motor driver
- Leadership in High Voltage MOSFET
- Wide bandgap transistors (SiC & GaN)

**Security**
- Secure element for medial data integrity
- M2M-SIM for authentication and confidentiality
- Enabling Blockchain transactions

**Connectivity**
- Short-range low-power BLE, NFC
- Long range IoT (Sigfox, LoRa)
- Cellular broadband, narrowband

**Targeting a broad range of applications**
- Medical Imaging
- Focused Ultrasound
- Energy Harvesting and Neurostimulators
- Non-Destructive testing
- Electrocardiography (ECG)
- Photoplethysmography (PPG)
- Galvanic Skin Resistance (GSR)
- Bio Impedance functionalities
- Oxygen saturation
- Respiratory Rate
- Skin Temperature

*MEMS = Micro-Electro-Mechanical Systems fabricated at Silicon level*
Ventilator detailed block diagram
Part 1 – Sensor stages and motor control

Sensor Stage
- Motion
- Microphone
- Flow Sensor
- Temperature Sensor
- Humidity Sensor
- Pressure Sensor
- Water Level

Water Container

3ph Motor Pump

Oxygen
Filtered Air

Power MOSFET
Power MOSFET
Power MOSFET

Monolithic or Integrated Motor Drivers
Power Switch
MOS / IGBT drivers
Control Logic

Connectivity, security and UI

MCU
**Acquiring data**

**Sensors to boost the performance and increase the comfort**

- **Motion sensors**
  - **Accelerometer** [IIS2DLPC]
  - **6X IMU** [ISM330DLC]
    - Ultra compact size, Low power, digital, cost effective
    - Enable the monitoring of posture and movements of the mask and patient head and optimize the airflow
    - Guaranteed for 10 years availability

- **Pressure sensors**
  - **Barometric sensor** [LPS22HH]
    - Water resistant [LPS27HHW, LPS33HW]
    - Ultra compact size, high robustness and reliability, Low power, digital, cost effective
    - Enable monitoring the breathing to optimize the airflow

- **Microphones**
  - **Digital MEMS microphone** [IMP34DT05]
    - High performance, digital
    - Enable voice command and, together with pressure sensor, allow the monitoring of the breathing to optimize the airflow
    - Guaranteed for 10 years availability

- **Temperature & humidity sensors**
  - **Temperature** [STTS2H]
    - **Temperature + humidity** [HTS221]
    - High accuracy, Ultra compact size, digital
    - Monitoring environmental conditions (temperature & humidity) enable to optimize the airflow and improve the comfort of the patient
Time of Flight Sensors to monitor water level in the tank and Mask positioning

Proximity [VL6180]
Distance Sensors [VL53L0X] [VL53L1X]
- Measure Water Level
- Monitor Mask Distance from face
- People counting or Presence detection

Complementary uses of Imaging Sensors

Ambient Light and Color sensors
Tiny color sensors for Lux/CCT and Flicker capture

Advanced Imager for computer vision
Global Shutter, High Sensitivity Vis and nIR, HDR, flicker free

Applications
- Proximity, ranging and Presence detection
- Gesture control
- Computer vision (Barcode scanning…)
- Screen brightness control for patient comfort
Current Sensing and Signal Conditioning

Current Sensing

- Low / High side current sense amplifier [TSC1xx, TSC2xx]
  - wide range of common mode voltages from -0.3 to +26 V
  - Offset voltage: ±35 µV max
  - Gain drift: 20 ppm/°C max

Signal Conditioning

- Operation Amplifiers [TSV9xx, TSV6xx, TSZ1xx]
  - Low-side current measurement for motor control
  - Very-high-accuracy, (5 µV) zero-drift, micropower 5 V op amp
## STM32 for healthcare application

### A broad offering

<table>
<thead>
<tr>
<th>High perf MCUs</th>
<th>Mainstream MCUs</th>
<th>Ultra-low power MCUs</th>
<th>Wireless MCUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>STM32F0 106 CoreMark 48 MHz</td>
<td>STM32G0 142 CoreMark 64 MHz</td>
<td>STM32L0 75 CoreMark 32 MHz</td>
<td>STM32WL 161 CoreMark 48 MHz</td>
</tr>
<tr>
<td>STM32F1 177 CoreMark 72 MHz</td>
<td>STM32F2 398 CoreMark 120 MHz</td>
<td>STM32L1 93 CoreMark 32 MHz</td>
<td>STM32WB 216 CoreMark 64 MHz</td>
</tr>
<tr>
<td>STM32F3 245 CoreMark 72 MHz</td>
<td>STM32F4 608 CoreMark 180 MHz</td>
<td>STM32L5 424 CoreMark 110 MHz</td>
<td></td>
</tr>
<tr>
<td>STM32F5 550 CoreMark 170 MHz</td>
<td>STM32H7 3224 CoreMark 240 MHz Cortex -M4 480 MHz Cortex -M7</td>
<td>STM32L4 273 CoreMark 80 MHz</td>
<td></td>
</tr>
<tr>
<td>STM32F7 1082 CoreMark 216 MHz</td>
<td></td>
<td>STM32L4+ 409 CoreMark 120 MHz</td>
<td></td>
</tr>
<tr>
<td>STM32MP1 4158 CoreMark 650 MHz Cortex -A7</td>
<td></td>
<td>STM32WB 216 CoreMark 64 MHz</td>
<td></td>
</tr>
</tbody>
</table>

### Arm® Cortex® core

- M0
- M0+
- M3
- M33
- M4
- M7
dual -A7 & -M4

- Cortex-M0+ Radio co-processor

### Optimized for mixed-signal applications

### Optimized for low power applications

- STM32L0 75 CoreMark 32 MHz
- STM32L1 93 CoreMark 32 MHz
- STM32L5 424 CoreMark 110 MHz
- STM32L4+ 409 CoreMark 120 MHz
- STM32WL 161 CoreMark 48 MHz
- STM32WB 216 CoreMark 64 MHz
STM32G4 series

Ideal for applications requiring an MCU that offers advanced and rich analog peripherals

Performance
- 213 DMIPS and 550 CoreMark® results
- Better dynamic power consumption (163 µA/MHz)
- Mathematical accelerators

Rich Integrated Analog and Digital
- Op-Amps (Built-in gain), DACs, Comparators
- 12-bit ADCs 4Msps with hardware oversampling
- High resolution timer (184 ps)
- USB type-C Power Delivery 3.0

Safety and security focus
- Dual Bank Flash with ECC (error code correction)
- Securable Memory Area
- Hardware encryption AES-256
- SIL, Class-B
- SRAM with Parity bit

KEY BENEFITS FOR VENTILATORS
- Easy interfacing with motor drivers and sensor stages
- Low power consumption to address portable devices
- Built-in security features

Secure Live Upgrade
Functional safety design packages
STM32L5 series

Ideal for applications requiring an MCU that offers advanced and rich analog peripherals

Security focus
Protection from hackers

Very power consumption
Long lifetime, small battery size

Integration, size & performance
Best fit to application requirements

Security: TrustZone for isolation

STM32L5

Un-Trusted

Trusted

Un-Trusted & Privileged

Trusted & Privileged

Un-Trusted

Secured Keys

Secured Boot

Un-Privileged

RTOS

RF Stack

Secured data

Sensor IP

RF

Sensors
STM32H7 series

The best choice for controls, indicators, and interfaces of ventilators

- **New performance record**
  2424 + 800 CoreMark (Cortex©-M7 @480Mhz + Cortex©-M4 @240Mhz)

- **Display nice graphics**
  The Chrom-ART Accelerator and MJPEG coded, offload the CPU by more than 90%

- **Advanced security features**
  Crypto Hash, Cortex©-M7 Security services

- **Rich eco-system to speed-up your design**
  SW tools, HW boards, community and partners
Motor control

Leading integration, performance, efficiency

Monolithic Low Voltage
STSPIN2 Series

Monolithic
STSPIN8 Series

Monolithic
L647 Series, L620, L622 Series

System-in-Package
PowerSTEP Series

Controllers: STSPIN32 Series, L648 Series

Applications up to 10 W

Applications up to 70 W

Applications up to 500 W

- Wide V & I ranges supported
  - 1.8 V – 85 V
  - 0.6 A_{RMS} – 3 A_{RMS}

- Intelligent top class 3phase BLDC drivers
- State of the art products and features for Stepper motors
STSPIN800 series motor drivers

Compact, energy conscious and cost-competitive motor drivers

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>$V_{IN\ min}$ (V)</th>
<th>$V_{IN\ max}$ (V)</th>
<th>$R_{DSON\ HS+LS}$ (Ohm)</th>
<th>$I_{OUT\ max}$ (Arms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STSPIN820</td>
<td>Microstepping driver up to 256 microsteps</td>
<td>7</td>
<td>45</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>STSPIN830</td>
<td>3-phase 3shunts BLDC motor driver</td>
<td>7</td>
<td>45</td>
<td>1 (0.5 *)</td>
<td>1.5 (3 *)</td>
</tr>
<tr>
<td>STSPIN840</td>
<td>Dual brushed DC motor driver</td>
<td>7</td>
<td>45</td>
<td>1 (0.5 *)</td>
<td>1.5 (3 *)</td>
</tr>
</tbody>
</table>

(*) Features allowed in parallel mode driving

KEY BENEFITS FOR VENTILATORS

High efficiency
- Standby mode to minimize power consumption in idle state (<50μA)

Smooth and silent motion
- Smooth and silent motion thanks to I control and 256 μsteps
- FOC & 6-step FW support

Reliable thanks to full set of protections
- UVLO, non-dissipative over-current and thermal protection
Stepper motor solutions: L647x & L648x

Highly autonomous solutions using high-level motion commands from system host

<table>
<thead>
<tr>
<th>Topology</th>
<th>Product</th>
<th>Description</th>
<th>$V_{\text{IN min}}$ (V)</th>
<th>$V_{\text{IN max}}$ (V)</th>
<th>$R_{\text{DSON}}$ (Ohm)</th>
<th>$I_{\text{OUT max}}$ (Arms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Drivers</td>
<td>L6470</td>
<td>Voltage mode driving algorithm (1/128 μstep)</td>
<td>8</td>
<td>45</td>
<td>0.3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>L6472</td>
<td>Predictive current control Adaptive decay (1/16 μstep)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L6474</td>
<td>Adaptive decay(1/16 μstep)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controllers</td>
<td>L6480</td>
<td>Voltage mode driving algorithm (1/128 μstep)</td>
<td>7.5</td>
<td>85</td>
<td>not applicable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L6482</td>
<td>Predictive current control Adaptive decay (1/16 μstep)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**KEY BENEFITS FOR VENTILATORS**

- **System stability and low noise**
  - System stability and low noise:
  - Adaptive auto regulated decay (slow /fast /mixed decay) (*)

- **Accurate positioning and control**
  - Predictive current control (*)

- **Smooth & very silent motion**
  - Voltage mode control (*) ensure driving performance similar to BLDC ones

- **Power Scalability**
  - Using L648x controller with ST power MOSFET (F7 family)
  - (*) ST patented features
Motion Control Architecture

Best Fit for BLDC: combining Power Density and Intelligence

**Architecture** | **Benefits**
--- | ---
1. **STSPIN32**
   - MCU + Driver
   - High integration (MCU + 3 Ph. Driver + DC-DC + LDO + Protection)
   - High performance control
   - High speed sensorless FOC

2. **STSPIN L6230**
   - Driver + MOS
   - Integrated Power Stage & Protections
   - Good cost-performance trade-off

3. **STDRIVE**
   - Discrete
   - Best flexible partitioning
   - Good cost-performance trade-off

**KEY BENEFITS FOR VENTILATORS**

Address all architectures of CPAP and Respirators

Cost effective sensor-less systems or accurate control with Hall-effect sensor feedback
Leader in High Voltage Silicon MOSFET

Complete family with wide product portfolio in terms of $R_{DS(on)}$, $BV_{dss}$ and packaging to reach the right mix for high efficiency and compactness solution.

**MDmesh™ series:**
- M2, M5 on PFC section
- M2, DM2, on DC/DC section
- NM, K5 on flyback

**Main Products**
- STF18N60M2
- STF40N60M2
- STY112N65M5
- STY145N65M5
- STP11NM80
- STD3N80K5
- STW40N95K5

**Customers:**
Delta, Edan, Megmeet, Plexus, Hechuan, Mindray, Medtronic, Philips, GE
High voltage silicon MOSFET series
Super-junction MDmesh™

Breakdown Voltage

- 600V
- 650V
- 800V – 1700V

MDmesh series

- M2
- M6
- DM2
- DM6
- M5
- DM2
- DM6
- K5

Focus Topology

- Flyback, PFC/LLC resonant conv.
- Flyback, PFC/LLC high efficiency
- HB / FB, ZVS, LLC high efficiency
- Hi-end-power PFC and hard switching topologies
- HB / FB, ZVS, LLC high power level
- HB / FB, ZVS, LLC high power level high efficiency
- Flyback topology

Focus Applications

- Charger adapters Led lighting, Medical
- Server, 5G, Consumer, Adapters, Solar, Medical
- Solar, Server, Telecom SMPS, EV-Car/Charging, Medical
- LED driver, LED lighting, auxiliary SMPS, EV-Car, Medical
Ventilator detailed block diagram
Part 2 – Connectivity, security and User Interface
Secure Element: STSAFE-A

Secure element for brand protection and secure connections

Secure the connected devices
• Authentication
• Secure connection
• Secure data storage
• Signature verification
• Common criteria certified

Protect your brand (consumables / peripherals)
• Digital Motion Engine
• High-level motion commands

At home
• Identification of devices using Unique ID in silicon
• SW integrity of devices via a Secure Boot process
• Integrity of patient data with digital signature
• Confidentiality via encryption

At the hospital
• Authentication
• Secure connection
• Secure data storage
• Signature verification
• Common criteria certified

STSAFE-A110
Enriched secure connection & LPWAN
• Generic pre-personalized samples
• STM32 Nucleo Expansion board
• STM32Cube Software package

Available @ distribution
M2M-eSIM: ST4SIM solution

A wide range of cellular connectivity solutions

Connection Health
Patient care from home

ST4SIM

• Wide range SIM/eSIM solutions based on Basic, Cryptographic and GSMA SGP.02 configurations
• GSMA eSIM certified and interoperable with MNOs & Subscription Management platform
• Complete ecosystem with trusted partners for connectivity & Subscription Management Platform
• Industrial & automotive grade solutions (T° & reliability)
• Multiple packages format (4FF, MFF2, WLCSP, TSSOP20)
NFC main use cases & benefits

**NFC Tag usage in medical**

**Configuration & Data logging**
- Product configuration and parameter settings through NFC
- Data log transferred, processed and plotted on NFC phone

**Servicing & Maintenance**
- Contactless access to maintenance records
- Update parameters even if device is powered off thanks to NFC phone
- Quick firmware upgrade via fast transfer mode

**Enhanced user experience**
- Wireless pairing
- Access to web page (URL) or get link for Android (AAR) or iOS application
- E-warranty card & customer registration
- Device control with mobile phone
- User identification & personalized settings

- Interactive and zero power technology (Tag powered by Reader)
- Convenient product configuration and maintenance
- Simple and flexible
Typical NFC tag block diagrams and use in medical equipment

**Healthcare equipment**

**ST25TV02K / ST25TA02KB**
- TruST25 digital signature
- Passwords
- Easy & fast data transfer
- Enhanced user experience

**ST25DV04K / 16K / 64K**
- I²C fast interface
- Fast Transfer Mode
- Large memory storage
- Configuration & data logging
- Servicing & Maintenance
- Enhanced user experience

**ST25R3911B / 12 / 13**
- High output power
- Low power consumption
- Automatic antenna tuning
- Configuration & data logging
- Servicing & Maintenance
UHF main use cases & benefits

Real-time patient tracking
- Log & monitor the progress of a person
- Locate people in real time
- Speed up bed turnover to admit more patients efficiently

Asset management
- Locate medical equipment
- Update parameters
- Speed up inventory management

- Fast detection and long read range
- Possibility of identifying more than 200 tags without constraint of positioning
- Cheapest tag to manufacture

UHF Reader
- ST25RU
- RAM
- SPI
- LCD Panel
- Key Pad
- Sensors
- Battery

ST25RU3993
- Long read range
- Low power consumption
- Fast read speeds

Real-time patient tracking
Drug asset management
ST low-power RF product lines connectivity, efficiency and robustness

Enabling the Sensor-to-Cloud wireless connectivity

BlueNRG Family

- Simplified HMI
- Easy customization
- Remote reading
- Service and maintenance
- Firmware upgrade
- Added-value services

BlueNRG-MESH

Companion Balun and Filter
BALF-NRG-01D3
BALF-NRG-02D3

Scalable packages
QFN48 6 x 6 mm
QFN32 5 x 5 mm
WLCSP34 2.66 x 2.56 mm
**S2-LP family overview**

**SPIRIT Family**

- Sub-1GHz Radio Transceivers and LPWAN networking
- Companion Balun and Filter
  - BALF-SPI2-01D3
  - BALF-SPI2-02D3

**Performance**

**S2-LP / S2-LPCB / S2-LPTX**
- 413-479 MHz / 826-958 MHz
- 452-527 MHz / 904-1055 MHz (**)
- -40°C to +105°C
- QFN24 4x4x1

**Radio performance**
- 100 bps to 500 kbps
- -130 dBm @ 0.3kbps (*)
- +16 dBm output power

**Ultra low-power consumption**
- Sleep / Shutdown: 700nA / 2.5nA
- Rx peak: 7 mA (*)
- Tx peak: 10 mA @+10dBm

(*) RX Feature only available on transceivers: S2-LP and S2-LPCB
(**) Frequency bands only available on S2-LPCB
BlueNRG-M0L
BlueNRG-M0A

- Based on BlueNRG-MS
- BLE4.2 certification
- Including high efficient chip antenna, filter and balun BALF-NRG-01D3

BlueNRG-M2SA
BlueNRG-M2SP

- Based on BlueNRG-2
- BLE5.0 certification
- Including high efficient chip antenna [-M2SA] or PCB antenna [-M2SP], filter and balun BALF-NRG-02D3

SPSGRF-868
SPSGRF-915

- Antenna option
- Two carrier frequency versions: 868 MHz & 915 MHz
- Including filter and balun BALF-SPI-02D3 for the SPSGRF-868.

SPSGRFC-433
SPSGRFC-868
SPSGRFC-915

- Connector option
- Three carrier frequency versions: 433 MHz, 868 MHz and 915 MHz
- Including filter and balun BALF-SPI-01D3 for the SPSGRF-433.
ST protections increase EMC robustness

High system immunity for all MCU interfaces
Thank you