Datasheet for conditioning sensor

Model: A2E-TRI

Updated 27th March 2026

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Description

The A2E-TRI is a PoE powered accelerometer for 10/100Mbit Ethernet networks.
It features a high performance, low noise sensor with very high sampling rate of 26.7kHz and a wide bandwidth.
The sensor is enclosed in an IP67 CNC machined aluminum enclosure, fully potted.

Control communication is done securely over UDP, and data transmissions are over TCP, streaming 256 samples in each packet. The protocol used for configuration and data is google's protobuf.

Specifications Overview

Electrical Specifications

Parameter	Value
Supply Voltage	48 V (PoE) IEEE 802.3af/at compatible
Power Consumption	< 2 W Typical operation
Interface	10/100 Ethernet - Auto-negotiation
Protocols	TCP (data), UDP (config) - Protobuf-based
Sampling Rate	Configurable 104 Hz to 26.7 kHz
Output Data Format	Signed 16-bit integers
Axes	Configurable single / dual or 3-axis simultaneously
Full Scale Range	±2g / ±4g / ±8g / ±16g
Bandwidth	Up to ~6.3 kHz, configurable
Packet Size	256 samples / packet
Time Synchronization	NTP supported

Mechanical Specifications

Parameter	Value
Enclosure	CNC machined aluminum, Fully potted
Protection Rating	IP67
Mounting	Bolt-on (flat surface)

Parameter	Value
Connector	M12 D-coded Industrial Ethernet
Dimensions	67 × 42 × 19.6 mm
Weight	~112 g
Operating Temperature	-40°C to +75°C

System Overview

Physical Connection

The A2E-TRI sensor connects using a single **M12 D-coded Ethernet cable**, which provides both:

- Power (PoE)
- Data communication

No additional wiring is required.

Data Flow

The sensor operates as a streaming device on a standard Ethernet network:

1. Sensor powers up via PoE
2. Network connection is established (DHCP or static IP)
3. A client connects via TCP
4. The sensor streams vibration data continuously

Communication Architecture

Function	Protocol	Description
Configuration	UDP	Low-overhead commands
Data Streaming	TCP	Reliable continuous data
Discovery	mDNS	Easy device detection

Data Format (Protobuf)

The A2E-TRI uses **Google Protocol Buffers (protobuf)** for all communication.

Benefits

- Compact binary format
- Fast parsing on embedded systems
- Open and cross-platform
- Easy integration in Python, C, C++, and other environments

Data Packet Structure

Each TCP packet contains:

- 256 samples per axis
- X, Y, Z acceleration data
- Optional timestamp

Example (conceptual)

```
message SensorData {
  repeated int16 x = 1;
  repeated int16 y = 2;
  repeated int16 z = 3;
  uint64 timestamp = 4;
}
```

Decoding the Data

To decode the data stream:

1. Open a TCP connection to the sensor
2. Receive protobuf binary data
3. Deserialize using a protobuf library

Supported Environments

- Python (recommended)
- C / C++
- Embedded systems

Sensor Configurations

Different sampling frequencies and low/high pass filters are possible.

Decimation setting

Decimation reduces the effective sampling rate by averaging multiple consecutive samples.

Setting	Description	Effective Output Rate	TCP Packages rate
1	No decimation (raw 26.7 kHz)	26.7 kHz	105 / second
2	Average every 2 samples	13.35 kHz	52 / second
4	Average every 4 samples	6.675 kHz	26 / second
8	Average every 8 samples	3.333 kHz	13 / second
16	Average every 16 samples	1.667 kHz	6.5 / second
32	Average every 32 samples	0.833 kHz	3.2 / second
64	Average every 64 samples	0.416 kHz	1.6 / second
128	Average every 128 samples	0.208 kHz	0.8 / second
256	Average every 256 samples	0.104 kHz	0.4 / second

Low-pass or High-pass filter options

An additional high or low pass filter can be enabled.

Setting	Bandwidth
ODR DIV 1	6.3 kHz
ODR DIV 4	1.56kHz
ODR DIV 10	0.63kHz

Setting	Bandwidth
ODR DIV 20	0.315kHz
ODR DIV 45	0.140kHz
ODR DIV 100	63Hz
ODR DIV 200	32Hz
ODR DIV 400	16Hz
ODR DIV 800	8.9Hz

Security Features

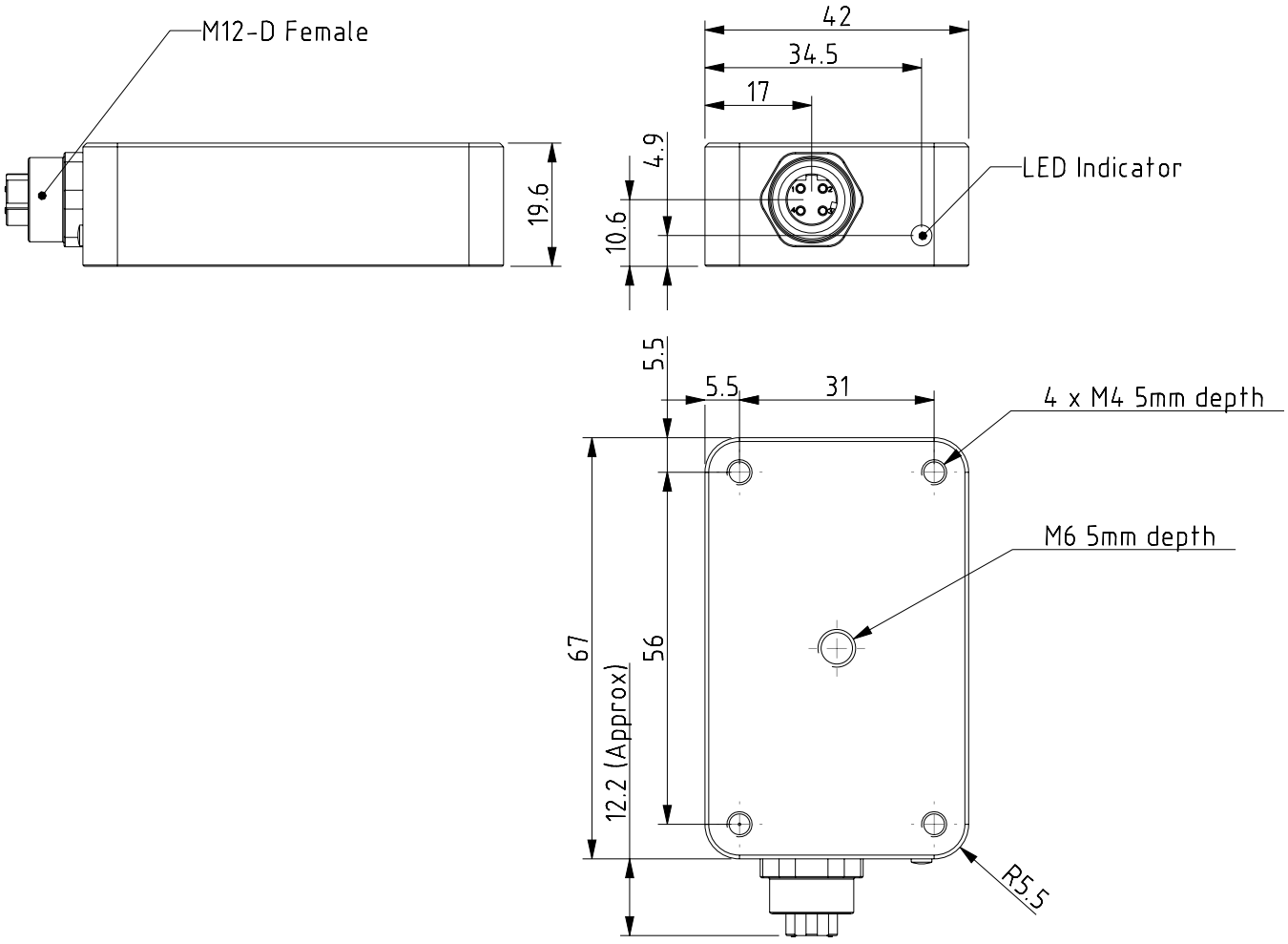
Secured by HMAC-MD5

Authentication for UDP configuration messages.

Encrypted secure boot

Ensures only trusted firmware is executed.

Mechanical Drawing



Feature	Detail
Mounting	4 × M4 threaded holes, 5 mm depth
Stud Mount	M6 thread
Connector	M12-D Female
Drawing Reference	ASSY_COMPLETE_REV4, Rev 1

All dimensions are in millimeters. Refer to the drawing above for full dimensional detail.

Connector & Pinout

The A2E-TRI uses an **M12 D-coded Female** connector per IEC 61076-2-101, the standard for Industrial Ethernet.

Pin	Signal	Description
1	TD+	Transmit Data +
2	RD+	Receive Data +
3	TD−	Transmit Data −
4	RD−	Receive Data −

Power over Ethernet (IEEE 802.3af/at) is delivered over the same four data pins. No separate power wiring is required.

Performance Characteristics

Parameter	Value
Full Scale Range	±2g / ±4g / ±8g / ±16g (selectable)
Native Sampling Rate	26.7 kHz
Output Resolution	16-bit signed integer
Sensitivity (±2g)	~0.061 mg/LSB
Noise Density (±2g)	~70 µg/√Hz typical
Operating Bandwidth	Up to 6.3 kHz (configurable via filter settings)
Axes	3-axis (X, Y, Z), individually or jointly selectable
Internal Temperature Sensors	2 × board sensors + 1 × MCU core

Sensitivity scales with full-scale range: higher ranges reduce sensitivity proportionally. Noise density is specified at the ±2g setting; it increases at higher full-scale ranges.

Data Throughput

Each TCP packet carries 256 samples per active axis as 16-bit integers (2 bytes/sample).

ODR Divider	Effective Rate	Data Rate (3-axis)	Data Rate (1-axis)	Packets/sec
1	26.7 kHz	~160 KB/s	~53 KB/s	~104
2	13.35 kHz	~80 KB/s	~27 KB/s	~52
4	6.675 kHz	~40 KB/s	~13 KB/s	~26
8	3.333 kHz	~20 KB/s	~6.7 KB/s	~13
16	1.667 kHz	~10 KB/s	~3.3 KB/s	~6.5
32	833 Hz	~5 KB/s	~1.7 KB/s	~3.3
64	417 Hz	~2.5 KB/s	~0.8 KB/s	~1.6
128	208 Hz	~1.2 KB/s	~0.4 KB/s	~0.8
256	104 Hz	~0.6 KB/s	~0.2 KB/s	~0.4

Calculation basis: Data rate = effective_rate × num_axes × 2 bytes/sample. Packets/sec = effective_rate / 256.

Each TCP packet includes additional framing overhead: a 4-byte big-endian length prefix and a protobuf header (~40–60 bytes depending on metadata).

Startup & Configuration

Boot Sequence

The device always starts in **bootloader mode** first. This ensures that even if the main application firmware is corrupted, the device remains recoverable via firmware update. The bootloader waits for a TFTP firmware update for a configurable timeout (typically **12 seconds**), during which it acquires an IP address. If no update is received, the main application starts automatically.

1. **Power on** via PoE (48 V, IEEE 802.3af/at)
2. **RED LED** illuminates briefly (power-on indication)
3. **1 second delay** — EEPROM initialization, all LEDs off
4. **Bootloader** — acquires IP, waits for firmware update (~12 s timeout)
5. **Main application starts** — network and sensor initialization begins
6. **Orange LED solid** — waiting for Ethernet link / DHCP
7. **Orange LED blinking (2 Hz)** — link established but NTP or TCP server not yet reachable
8. **Green LED solid** — fully connected (NTP synced, TCP connected), ready to stream
9. **Green LED blinking (2 Hz)** — actively streaming sensor data

Network Initialization

On startup, the device builds a hostname from the last two bytes of its MAC address (e.g. `vs15105.local`) and starts the **mDNS** responder. The mDNS service announces a `_nw-config._udp.local.` service with TXT data including:

```
Host: vs15105.local    Mac: 02:a0:12:63:3b:01  IP: 192.168.0.112    Port: 56671
Sensor: A2E_TRI  Versions: HW=3  FW App=4133  FW Boot=n/a, Lillie Systems Ltd
```

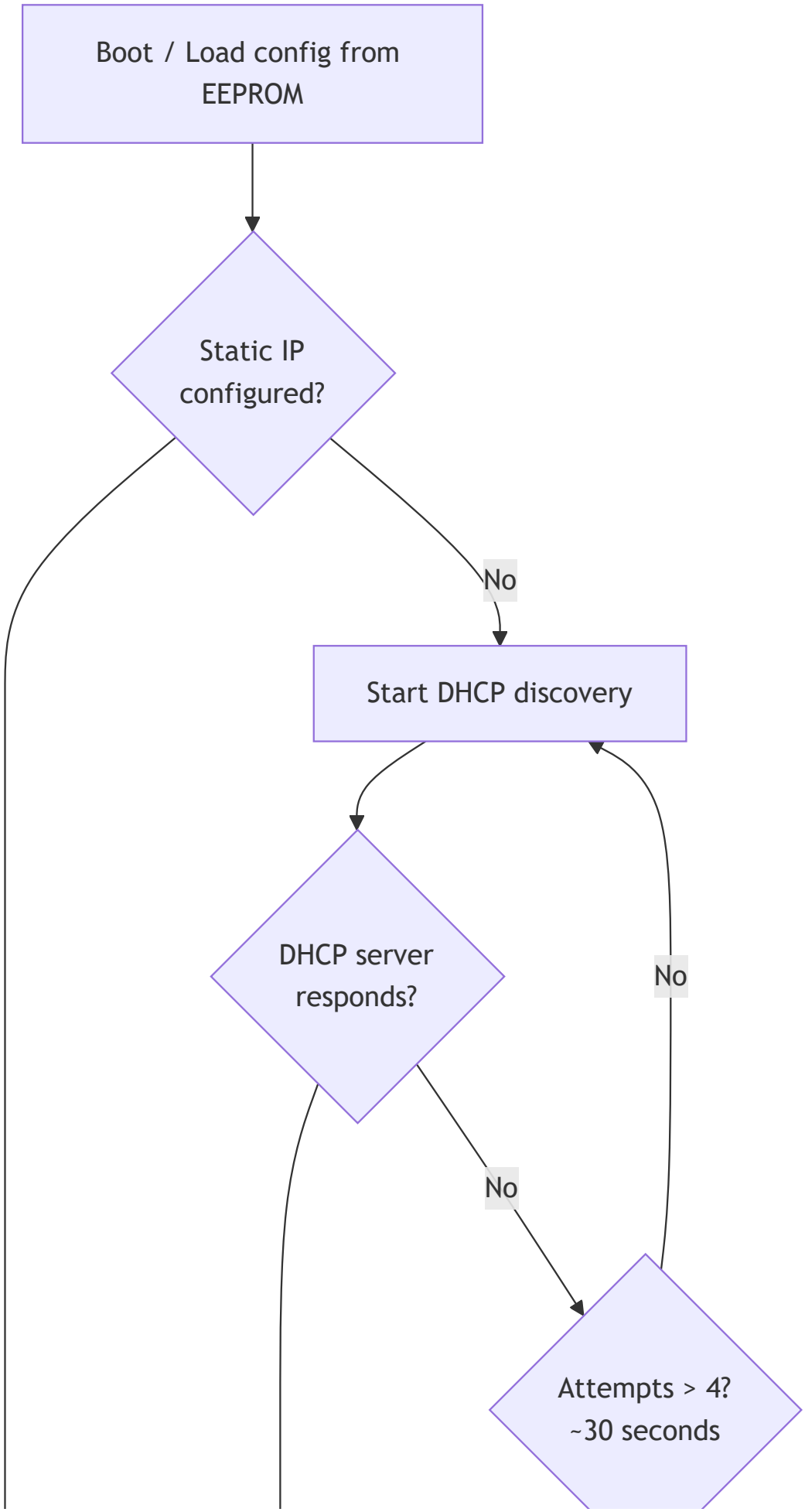
These fields allow discovery tools to identify units, firmware state, and differentiate between bootloader and application mode.

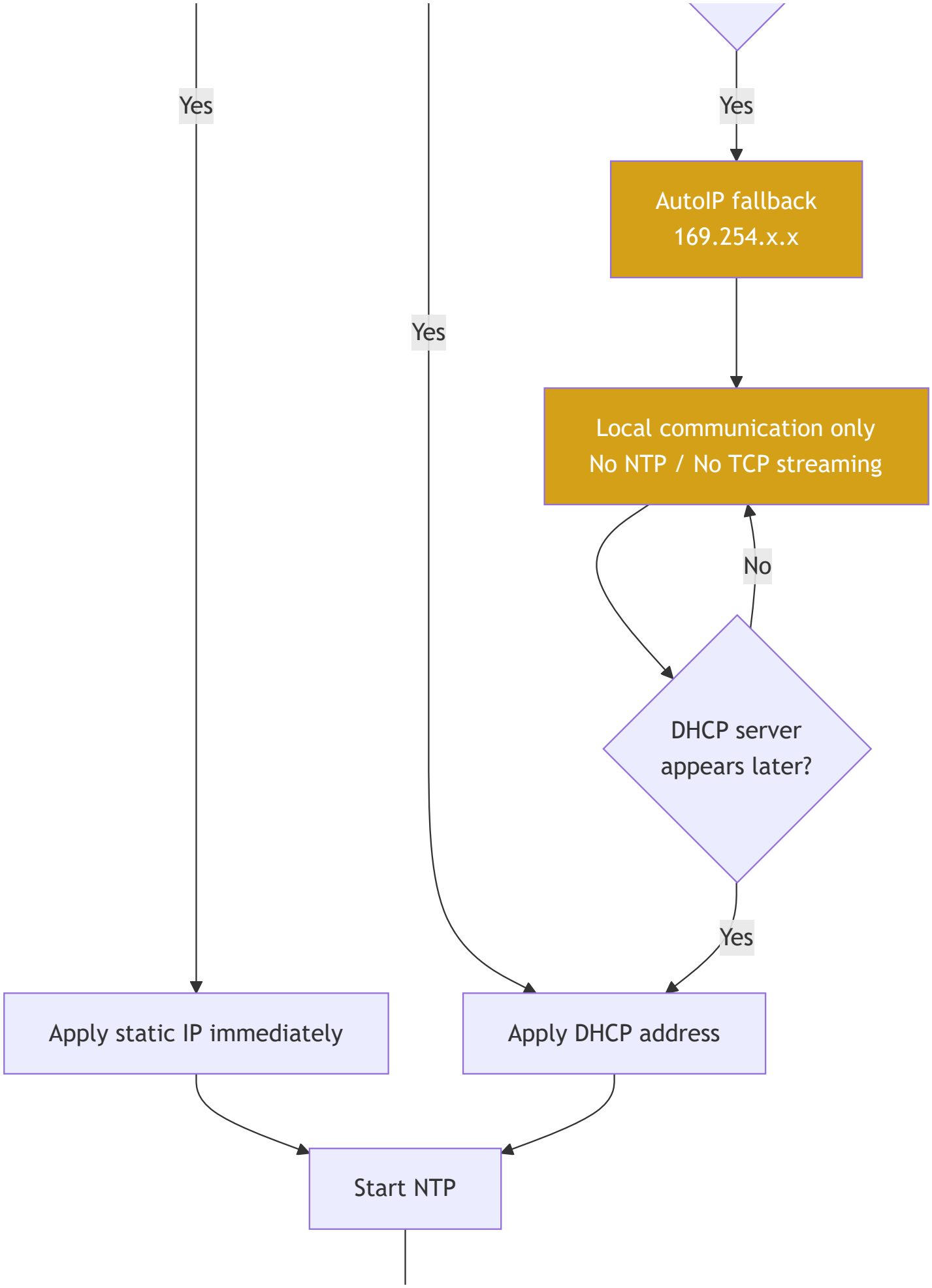
On boot, the firmware reads the network configuration from EEPROM. If a static IP address is configured, it is applied immediately and the device is ready. If no static IP is set (or DHCP is explicitly enabled), the device starts a DHCP discovery process with exponential backoff over approximately 30

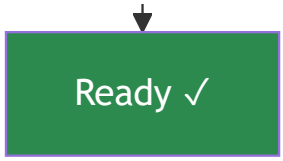
seconds. If no DHCP server responds within 4 attempts, LwIP's AutoIP assigns a link-local address in the `169.254.x.x` range (RFC 3927), allowing local communication without a DHCP server. NTP time synchronization is only started once a routable (non-link-local) IP is assigned. If a DHCP server appears later, the device automatically transitions from link-local to the assigned address.

The bootloader (SBSFU) follows a similar DHCP flow but falls back to a hardcoded static IP rather than link-local.

IP Assignment Flow


Boot / Load config from EEPROM
Static IP configured?
No
Start DHCP discovery
DHCP server responds?
No
No
Attempts > 4? ~30 seconds


Yes
Yes
Yes
AutoIP fallback
169.254.x.x
Local communication only
No NTP / No TCP streaming
No
DHCP server
appears later?
Yes
Apply static IP immediately
Apply DHCP address
Start NTP



Link State Changes

When the Ethernet link goes down and comes back up, the DHCP process restarts automatically. The LED shows solid orange while no IP is assigned.

Timing

Event	Timing
Static IP assignment	Immediate
DHCP attempt 1	~2 s
DHCP attempt 2	~6 s
DHCP attempt 3	~14 s
DHCP attempt 4	~30 s
AutoIP fallback	~30 s (after DHCP timeout)
First NTP poll	15 s after IP assigned
NTP poll interval	1 hour (configurable)

SNTP Time Synchronization

Once the interface has a valid routable IP (static or DHCP), the SNTP client synchronizes the device clock to network time using a configured NTP server IP at a configurable polling interval.

When a valid SNTP response is received, the device converts seconds and fractional seconds into a UNIX timestamp with nanosecond precision and compares it to the local high-resolution hardware timer. If the difference exceeds ~1 ms, the local timer base is updated to maintain timestamp accuracy. The hardware real-time clock (RTC) is also updated to UTC.

On the first successful sync, the SNTP polling interval changes to 1 hour (default) or to the user-configured interval.

Boot Modes

Mode	Description
Bootloader	Entered on every power-on. Acquires IP, waits for TFTP firmware update (~12 s). Also re-entered via `boot_now` command.
Application	Normal operating mode — sensor streams data. Starts automatically after bootloader timeout.

Configuration Persistence

All sensor and network settings are stored in non-volatile memory (EEPROM) and persist across power cycles. A `factory_reset` command restores all settings to defaults.

API / Software

Device Discovery

Devices are discoverable on the local network via **mDNS** using the service type:

```
_nw-config._udp.local.
```

This enables zero-configuration discovery without prior knowledge of the sensor's IP address. The mDNS TXT record includes hostname, MAC address, IP, port, sensor type, hardware and firmware versions, and manufacturer.

UDP Control Protocol

All configuration and command messages are sent over **UDP port 56671** using multicast address **224.0.0.251**.

Request Frame

Field	Size	Description
header_size	4 bytes	Fixed: 30 (total header length)
MAC address	6 bytes	Target device MAC (big-endian)
request_id	4 bytes	Unique request identifier
HMAC-MD5	16 bytes	Authentication digest
Protobuf payload	Variable	Serialized `Request` message

HMAC calculation: `HMAC-MD5(key=MD5(password), message=payload)`

Response Frame

Field	Size	Description
header_size	4 bytes	Fixed: 8 (total header length)
request_id	4 bytes	Matching request identifier
Protobuf payload	Variable	Serialized `Response` message

Available Commands

Command	Description
`get_sensor_info`	Returns device type, HW/FW/bootloader versions, temperatures (board × 2, MCU core), UTC time, error bits
`get_sensor_config`	Returns current sensor configuration
`set_sensor_config`	Sets full_scale, axes, odr_div, filter type, filter cutoff, fft_size
`get_network_config`	Returns IP, netmask, gateway, server IP/port, NTP, DHCP state, streaming state
`set_network_config`	Configures network parameters, DHCP, NTP, data/FFT streaming enable
`command: stream_data`	Enable or disable acceleration data streaming
`command: stream_fft`	Enable or disable FFT data streaming
`command: reset_device`	Reboot the sensor
`command: factory_reset`	Restore all settings to factory defaults
`command: boot_now`	Enter bootloader mode for firmware update
`new_app_password`	Change the application HMAC password
`new_factory_password`	Change the factory HMAC password
`calibration`	Trigger accelerometer calibration sequence

Command	Description
`get_factory_info`	Returns serial number, calibration offsets, manufacturing date

Sensor Configuration Parameters

Full Scale Range

Value	Enum
±2g	ACCEL_FS_2G
±4g	ACCEL_FS_4G
±8g	ACCEL_FS_8G
±16g	ACCEL_FS_16G

Axis Selection

Selection	Enum
X only	AXIS_X
Y only	AXIS_Y
Z only	AXIS_Z
X + Y	AXIS_XY
X + Z	AXIS_XZ
Y + Z	AXIS_YZ
X + Y + Z	AXIS_XYZ

Output Data Rate Divider

Divider	Effective Rate	Enum
1	26.7 kHz	ODR_DIV_1

Divider	Effective Rate	Enum
2	13.35 kHz	ODR_DIV_2
4	6.675 kHz	ODR_DIV_4
8	3.333 kHz	ODR_DIV_8
16	1.667 kHz	ODR_DIV_16
32	833 Hz	ODR_DIV_32
64	417 Hz	ODR_DIV_64
128	208 Hz	ODR_DIV_128
256	104 Hz	ODR_DIV_256

Digital Filter

Filter Type	Enum
None	FILTER_NONE
Low-pass 2nd order	FILTER_LOW_PASS2
High-pass	FILTER_HIGH_PASS
Slope filter	FILTER_SLOPE_FILTER

Filter Cutoff Frequency

Cutoff	Enum
6.66 kHz	CUTOFF_6p66_KHZ
2.66 kHz	CUTOFF_2p66_KHZ
1.33 kHz	CUTOFF_1p33_KHZ
590 Hz	CUTOFF_0p59_KHZ
260 Hz	CUTOFF_0p26_KHZ
130 Hz	CUTOFF_0p13_KHZ

Cutoff	Enum
60 Hz	CUTOFF_0p06_KHZ
30 Hz	CUTOFF_0p03_KHZ
None	CUTOFF_NONE

FFT Size

Bins	Enum
256	FFT_SIZE_256
512	FFT_SIZE_512
1024	FFT_SIZE_1024
2048	FFT_SIZE_2048

TCP Data Stream

The sensor streams data over TCP to the configured `server_ip:server_port`.

Framing

Each TCP message consists of:

1. **4-byte big-endian length prefix** — size of the protobuf payload
2. **Protobuf `Message`** — serialized binary payload

Message Structure

Field	Description
`msg_version`	Protocol version
`device_timestamp`	Timestamp of first sample (google.protobuf.Timestamp)
`device_id`	MAC address as 6-byte identifier

Field	Description
`device_sn`	Device serial number
`stream_uid`	Unique stream identifier
`sequence_number`	Packet sequence for loss detection
`flags`	FLAG_STREAM_END, FLAG_NO_TIME_SYNC, FLAG_TEST_RUN

Payload: FrameStream (Acceleration Data)

Field	Description
`frame_number`	Cumulative frame count since stream start
`frame_count`	Number of sample tuples in this packet (256)
`target_frequency_hz`	Requested sampling rate
`actual_frequency_hz`	Achieved sampling rate
`meta_data`	Per-axis metadata: data type, axis, unit, numpy format, scaling
`channel_id`	Logical data channel identifier

The raw payload bytes follow the metadata layout: each axis is sent as a contiguous block of `frame_count` samples in the format specified by `meta_data` (typically 16-bit signed integer, little-endian).

Payload: FFTStream (Frequency Domain Data)

Field	Description
`frame_number`	Cumulative FFT frame count
`frame_count`	Number of FFT frames in this packet
`duration_ns`	Time window duration in nanoseconds
`fft_bins`	Number of FFT output bins
`hop_size`	FFT hop size (overlap control)
`fft_window`	Windowing function: Hann, Hamming, or Blackman

Field	Description
`fft_result`	Result format: Magnitude or Complex
`actual_frame_rate_hz`	Input sample rate
`fft_frame_rate_hz`	FFT output rate (= actual_frame_rate / fft_bins)
`meta_data`	Per-axis metadata (same format as FrameStream)

Response Status Codes

Code	Meaning
RESPONSE_STATUS_OK	Command executed successfully
RESPONSE_STATUS_INVALID_PARAM	Invalid parameter in request
RESPONSE_STATUS_INVALID_HMAC	Authentication failed (wrong password)
RESPONSE_STATUS_INVALID_FULL_SCALE_RANGE	Full scale value out of range
RESPONSE_STATUS_INVALID_ODR	ODR divider value out of range
RESPONSE_STATUS_INVALID_AXIS_MASK	Invalid axis selection
RESPONSE_STATUS_INVALID_FILTER_SETTING	Invalid filter configuration
RESPONSE_STATUS_INVALID_NETMASK	Invalid subnet mask
RESPONSE_STATUS_INVALID_GATEWAY	Invalid gateway address
RESPONSE_STATUS_INVALID_NTP_INTERVAL	Invalid NTP sync interval
RESPONSE_STATUS_INVALID_DHCP_STATE	Invalid DHCP toggle value
RESPONSE_STATUS_INVALID_DATA_STREAM_STATE	Invalid data stream toggle value
RESPONSE_STATUS_UNKNOWN_ERROR	Unspecified internal error

Environmental & Compliance

Parameter	Value
Operating Temperature	−40°C to +75°C
Protection Rating	IP67
Enclosure	CNC machined aluminum, fully potted
CE Marking	Yes

Applicable Standards

Standard	Description
IEC 61000-4-2	Electrostatic discharge immunity
IEC 61000-4-3	Radiated electromagnetic field immunity
IEC 61000-4-4	Electrical fast transient / burst immunity
IEC 61000-4-5	Surge immunity
IEC 61000-4-6	Conducted disturbances immunity
IEC 61000-4-8	Power frequency magnetic field immunity
IEC 61000-6-4	Emission standard for industrial environments (Class A & B)

LED Indicators

Status LED

LED State	Color	Pattern	Condition
No network	Orange	Solid	Ethernet link DOWN (no IP / waiting for DHCP)
Partial connectivity	Orange	2 Hz blink	Link UP but NTP unreachable or TCP not connected
Ready	Green	Solid	Link UP, NTP synced, TCP connected, streaming disabled
Streaming	Green	2 Hz blink	All services connected, sensor data streaming active
Firmware update	Green	2 Hz blink	Receiving OTA firmware via TFTP
Error	Red	Solid	Critical error — system halted

Blink timing: 2 Hz (500 ms period), 50% duty cycle (250 ms ON / 250 ms OFF).

Ordering Information

Part Number	Description
TBD	A2E-TRI accelerometer sensor unit
TBD	M12 D-coded Ethernet cable (various lengths)
TBD	Mounting hardware kit

Revision History

Rev	Date	Author	Description
1.0	October 2025	Jacob Lillie	Initial release
2.0	27 March 2026	Jacob Lillie	Complete datasheet: mechanical drawing, connector pinout, API documentation, LED indicators, data throughput, startup sequence, performance characteristics, environmental & compliance