Kookabus-01

Dual battery hot-swap and I2C power monitor board

Datasheet, board revision 2. Document revision 1.0, 25 September 2026. Preliminary: values not marked as measured are from design calculations and component datasheets.

Adventures in Silicon Pty Ltd
Australia

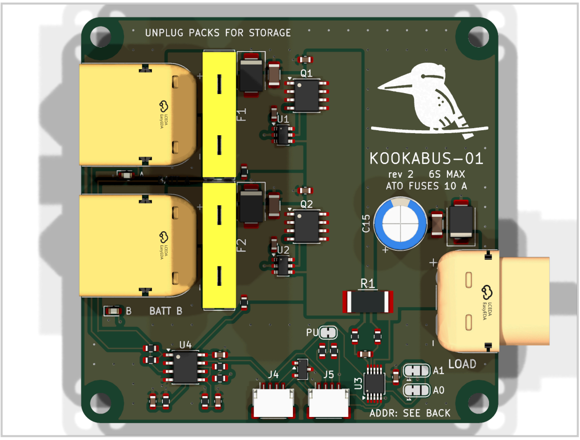

Figure 1. Top view. Battery inputs on the left, load output on the right, I2C connectors along the bottom edge.

Description

Kookabus-01 joins two lithium-ion packs into one uninterrupted supply for a robot or other mobile load. Each pack feeds an ideal-diode stage, so the higher-voltage pack carries the load and a pack can be unplugged and replaced while the other keeps the bus up. A high-side current and voltage sensor on the output reports bus voltage, current and power over I2C through two Qwiic/PiicoDev connectors. An LED beside each battery connector shows which pack is supplying the load.

The board is a power pass-through. It does not regulate, charge or balance, and it needs no configuration to swap packs: the ideal diodes run from the packs themselves. The sensor and LEDs draw their 3.3 V from the I2C host.

Applications

- Hot-swappable battery supply for ROS 2 and other mobile robots
- Battery monitoring for Raspberry Pi, Jetson and microcontroller hosts
- Bench supplies built from cordless-tool packs (Ryobi ONE+, Einhell Power X-Change and similar 5S packs on XT60 adapter leads)

Features

- Two XT60 battery inputs, one XT60 load output, common ground
- 5S lithium-ion packs as the primary target; every part rated for 6S (25.2 V)
- 100 W peak, 40 W continuous (6.7 A peak, 2.7 A continuous from a flat 15 V pack)
- Ideal-diode ORing: 20 mV regulated forward drop, no brownout on swap, reverse-current blocking
- Reverse-polarity tolerant inputs: a reversed pack is blocked, not shorted
- INA226 high-side monitor: 1.25 mV bus voltage LSB, 0.5 mA current LSB, 16 sample averaging
- I2C at 3.3 V logic, four selectable addresses (0x40 default), on-board pull-ups with a cut jumper
- Two Qwiic/PiicoDev connectors for daisy-chaining, with ESD protection on SDA and SCL
- One 10 A ATO blade fuse per pack, replaceable without tools
- Bidirectional 33 V TVS on each input, 26 V TVS on the output
- Active-pack indicator LEDs, red for A and yellow for B
- Standby drain about 0.32 mA per pack with the host off
- 64 x 62 mm, four M3 mounting holes, all SMD parts on the top side

1. Block diagram

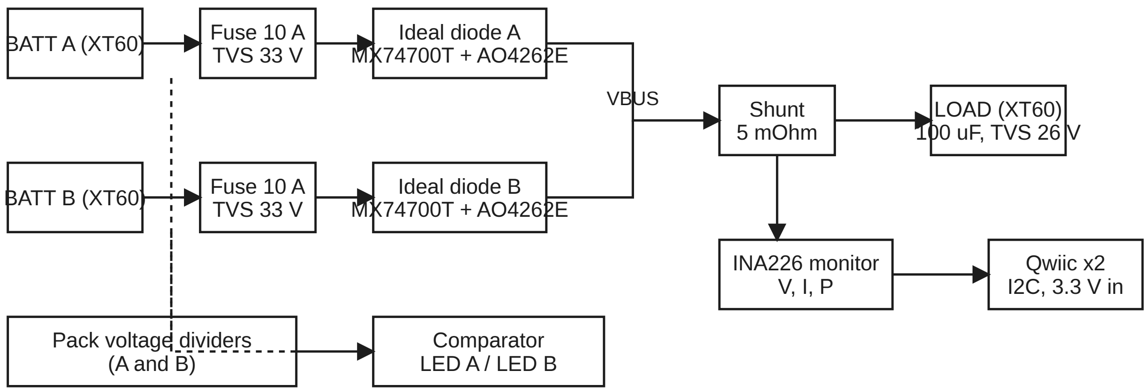

Figure 2. Signal flow. The power path runs left to right on the top copper layer; the bottom layer is a ground plane.

Only the pack with the higher voltage conducts. When the two packs are within about 20 mV of each other both stages conduct and share the load. When a pack is unplugged, the other pack's FET body diode conducts immediately and its controller then enhances the FET, so the bus never drops out. Current cannot flow back into a pack: a fully charged pack plugged in beside a flat one does not charge the flat one.

2. Absolute maximum ratings

Stresses beyond these values may cause permanent damage. These are limits, not operating conditions.

Parameter	Min	Max	Unit	Limiting part or note
Battery input voltage, BATT A or BATT B to GND	-26	33	V	SMBJ33CA standoff. Negative: a reversed 6S pack is blocked by the ideal diode (FET VDS 60 V, worst case 50.4 V with a 25.2 V bus).
Transient on a battery input (clamped)		53.3	V	TVS clamp at its rated 11.3 A surge, microseconds only.
Load output voltage, LOAD to GND	-0.3	26	V	SMBJ26A standoff. Voltage applied to the output from the load side (regen) is absorbed only by the output capacitor and TVS.
Load current, continuous		10	A	Fuse rating. Above about 8 A the fuse and copper run hot; see section 3.
3V3 pin (Qwiic connector) to GND	-0.3	5.5	V	INA226 supply limit.
SDA, SCL to GND	-0.3	5.5	V	PESD5V0S2BT clamps ESD; INA226 and pull-up rail set the DC limit.
ESD on SDA, SCL (IEC 61000-4-2, contact)		8	kV	PESD5V0S2BT.
Operating ambient temperature	-20	70	°C	Limited by the electrolytic output capacitor and connectors. Not characterised over temperature.
Storage temperature	-40	85	°C	Packs unplugged.

3. Recommended operating conditions

Parameter	Min	Typ	Max	Unit	Note
Pack voltage, each input	12	18	25.2	V	5S primary (15.0 V flat to 21.0 V full); 6S full charge is the maximum. The ideal-diode controllers work from 3.2 V but the sense and LED circuits are meant for 5S to 6S.
Pack chemistry					Lithium-ion or LiPo, 5S or 6S. Any chemistry in the voltage range works; the board does not charge or balance.
Load current, continuous		2.7	7	A	2.7 A is 40 W from a flat 5S pack. 7 A keeps every copper pour under a 10 °C rise (IPC-2221, 1 oz, external).
Load current, peak (10 s)		6.7	10	A	6.7 A is 100 W from a flat 5S pack.
Load power from a 5S pack		40	100	W	Continuous, peak.
3V3 supply from the host	3.0	3.3	3.6	V	Qwiic/PiicoDev standard. Below 2.7 V the INA226 resets.
3V3 supply current drawn from the host		2	4	mA	INA226, comparator and one lit LED.
I2C bus speed		400	2500	kHz	INA226 supports up to 2.94 MHz high-speed mode; 100 or 400 kHz is typical for Qwiic cabling.
Operating ambient temperature	0	25	50	°C	At 100 W the FET rises about 30 °C above ambient in still air.

4. Electrical characteristics

Calculated at 25 °C from component datasheets unless stated. VBUS is the ORed node after the ideal diodes; VLOAD is the load connector after the shunt.

4.1 Power path

Parameter	Condition	Min	Typ	Max	Unit
Ideal-diode regulated forward drop (BATT to VBUS)	Load below about 3 A	13	20	29	mV
FET on-resistance (per stage)	VGS about 12 V, 25 °C / 125 °C junction			6.5 / 10.5	mOhm
Total input to output drop, fuse to LOAD	2.7 A (40 W)		70		mV
	6.7 A (100 W), FET hot		190		mV
Series resistance, fuse to LOAD (excluding the regulated drop)	Fuse 7.7 mOhm, FET, shunt 5 mOhm, copper, connectors		30		mOhm
Board dissipation	2.7 A / 6.7 A		0.18 / 1.25		W
Pack sharing window	Both stages conduct when packs are within		20		mV
Reverse current, VBUS into a pack	Lower pack, or pack removed		0		A
Time to enhance the FET on first connection	Body diode carries the load until then		2.3		ms

Parameter	Condition	Min	Typ	Max	Unit
Ideal-diode controller supply current, per pack	Always, from the pack		300		uA
Standby drain per pack, host off	Controller plus pack-voltage divider		0.32		mA
Output capacitance on VLOAD	100 uF electrolytic plus 4.7 uF ceramic		105		uF
Input capacitance, each pack	4.7 uF 50 V ceramic		4.7		uF

4.2 Monitor (INA226, U3)

Parameter	Condition	Min	Typ	Max	Unit
Bus voltage measurement point	VLOAD, the load side of the shunt	0		36	V
Bus voltage LSB	Register 0x02		1.25		mV
Bus voltage error relative to the live pack	Series drop at 40 W / 100 W; add back I x 0.03 Ohm if wanted		-0.07 / -0.19		V
Shunt resistance	2512 alloy, 3 W, 50 ppm/°C, Kelvin sensed		5		mOhm, 1 %
Shunt voltage LSB	Register 0x01		2.5		uV
Current full scale	81.92 mV / 5 mOhm		±16.4		A
Current LSB	CALIBRATION = 2048		0.5		mA
Current offset	INA226 10 uV input offset		2		mA
Current gain error	Shunt tolerance plus INA226 0.1 %			1.1	%
Power LSB	25 x current LSB		12.5		mW
Conversion time, bus and shunt	Default 1.1 ms each, 1 sample	0.14	1.1	8.2	ms
Sense input filter	10 Ohm series, 100 nF differential		80		kHz

4.3 Indicators and I2C

Parameter	Condition	Typ	Unit
LED A (red) lit	Pack A voltage above pack B, host 3.3 V present		
LED B (yellow) lit	Pack B voltage above pack A, host 3.3 V present		
Indicator hysteresis	Other pack must be higher by this amount before the LED changes over	0.33	V
Indicator channel mismatch	1 % dividers; either LED may light when packs are closer than this	0.2 (0.8 max)	V
LED current	1 kOhm from 3.3 V	1.4	mA
I2C pull-up, SDA and SCL	To 3V3 through jumper JP3 (fitted, bridged)	4.7	kOhm
I2C address	JP1 and JP2 as supplied	0x40	

5. Connectors and jumpers

5.1 Power connectors

Ref	Label	Part	Pin 1	Pin 2	Note
J1	BATT A	Amass XT60PW-M (male, PCB)	GND	+ (PACK_A)	Mates with a female XT60 pack lead. Polarity is marked on the silkscreen.
J2	BATT B	Amass XT60PW-M (male, PCB)	GND	+ (PACK_B)	As J1.
J3	LOAD	Amass XT60PW-F (female, PCB)	GND	+ (VLOAD)	Female so a pack lead cannot be plugged into the output. Its nose extends 7.8 mm past the board edge so the load plug's shroud slides over it.

All three connectors share one ground. There is no isolation between the packs, the load and the I2C host.

5.2 I2C connectors

Ref	Part	Pin 1	Pin 2	Pin 3	Pin 4
J4, J5	JST SH 1.0 mm 4-way horizontal (SM04B-SRSS-TB compatible)	GND	3V3 (in)	SDA	SCL

The pin order is the Qwiic and PiicoDev standard, so any Qwiic cable connects directly. J4 and J5 are wired in parallel for daisy-chaining. The host must supply 3.3 V on pin 2: the board has no regulator of its own, and the monitor, comparator and LEDs stay off until it does. The hot-swap function does not depend on the host.

5.3 Solder jumpers

Ref	Silkscreen	Function	As supplied
JP1	A0	INA226 address pin A0: three pads, centre to GND side or VS (3V3) side	GND side bridged
JP2	A1	INA226 address pin A1: three pads, centre to GND side or VS side	GND side bridged
JP3	PU	Connects the 4.7 kOhm SDA and SCL pull-ups to 3V3. Cut the trace between the pads to remove the pull-ups when the host or another board already provides them.	Bridged (pull-ups on)

5.4 I2C address selection

JP2 (A1)	JP1 (A0)	Address (7-bit)
GND	GND	0x40 (default)
GND	VS	0x41
VS	GND	0x44
VS	VS	0x45

To change an address, cut the bridged trace on the GND side of the jumper, then bridge the centre pad to the VS side with solder. The table is also printed on the back of the board. Up to four Kookabus-01 boards can share one I2C bus.

5.5 Fuses

F1 (pack A) and F2 (pack B) are ATO/ATC blade fuse holders rated 30 A at 60 V. Fit a 10 A, 32 V ATO blade fuse in each (Littelfuse 0287010.PXCN or any equivalent). The fuses ship separately and must be fitted before use. A fuse on each pack, rather than one on the output, also protects against a short in that pack's input TVS, capacitor or FET. Blade fuses break more than 1 kA at 32 V, which a tool pack can deliver into a short.

6. I2C interface

The only I2C device on the board is the Texas Instruments INA226. Its register map applies unchanged; the values below are specific to this board's 5 mOhm shunt. Registers are 16 bits, most significant byte first.

Address	Register	Use on Kookabus-01
0x00	Configuration	Reset value 0x4127 (1 sample, 1.1 ms conversions, continuous). Write 0x4527 for 16 sample averaging, which steadies readings with a motor load.
0x01	Shunt voltage	Signed, 2.5 uV per LSB. Current in amps = value x 2.5e-6 / 0.005.
0x02	Bus voltage	Unsigned, 1.25 mV per LSB. Valid straight after power-up with no configuration.
0x03	Power	Unsigned, 12.5 mW per LSB once CALIBRATION is written.
0x04	Current	Signed, 0.5 mA per LSB once CALIBRATION is written. Positive is current into the load.
0x05	Calibration	Write 2048 (0x0800) after every power-up of the host 3.3 V. Formula: 0.00512 / (0.0005 A x 0.005 Ohm).
0x06, 0x07	Mask/Enable, Alert limit	Usable, but the ALERT pin is not brought out.
0xFE, 0xFF	Manufacturer ID, Die ID	Read 0x5449 and 0x2260 to confirm the device is present.

> The INA226 loses its configuration whenever the host's 3.3 V is removed. Write CALIBRATION (and CONFIG if changed) in the host's start-up code, not once at commissioning.

6.1 Example (Linux, Python, smbus2)

```
from smbus2 import SMBus

ADDR = 0x40
with SMBus(1) as bus:
    def rd(reg):
        b = bus.read_i2c_block_data(ADDR, reg, 2)
        return (b[0] << 8) | b[1]
    def wr(reg, val):
        bus.write_i2c_block_data(ADDR, reg, [val >> 8, val & 0xFF])

    assert rd(0xFE) == 0x5449          # INA226 present
    wr(0x00, 0x4527)                   # 16 sample average, continuous
    wr(0x05, 2048)                     # 0.5 mA per LSB with the 5 mOhm shunt
    volts = rd(0x02) * 1.25e-3
    raw = rd(0x04)
    amps = (raw - 65536 if raw > 32767 else raw) * 0.5e-3
    watts = rd(0x03) * 12.5e-3
    print(f"{volts:.2f} V  {amps:.3f} A  {watts:.2f} W")
```

On Linux the kernel `ina2xx` hwmon driver also supports the part: declare it in the device tree with `compatible = "ti,ina226"` and `shunt-resistor = <5000>` (micro-ohms), and read voltage, current and power from sysfs.

6.2 State of charge

The bus voltage reads the live pack minus the series drop (section 4.2). For a percentage estimate, divide by the cell count and use a per-cell resting-voltage table rather than a straight line from 3.0 V to 4.2 V. Under load, correct for sag with the measured current and an estimate of pack resistance, which can be taken from the voltage step when the load changes. Integrating the current register gives a coulomb count for the pack that is currently supplying the load; the board cannot tell the host which pack that is, other than by the voltage reading itself.

7. Protection and safety

Event	Response
Pack unplugged under load	The other pack takes over with no interruption. The remaining pack's FET body diode conducts within nanoseconds; the controller then enhances the FET.
Pack plugged in reversed	Blocked. The ideal-diode FET stays off (VDS up to 50.4 V with a 6S bus, rated 60 V) and the bidirectional input TVS is off at -25.2 V. No current flows and nothing is damaged.
Lower-voltage pack connected beside a higher one	No current flows into the lower pack. It takes over when the higher pack discharges to within 20 mV of it.
Short on the load or a failed part on the board	The 10 A fuse of the conducting pack opens. Replace it with the same rating.
Voltage transient on an input (lead inductance, motor noise)	Clamped by the 33 V bidirectional TVS below the FET and controller limits.
Voltage rise on the output (regenerative braking)	The ideal diodes block current back into the packs, so only the 100 uF output capacitor and the 26 V TVS absorb it. Run motor controllers with regenerative braking disabled, or fit a brake resistor.
Pack over-discharge	Not protected on the board. The FET body diode always conducts, so the board cannot disconnect a pack. The host must stop the load at the pack's minimum voltage, or the pack must have its own cut-off.
Over-current below the fuse rating	Not protected. Currents between 7 A and 10 A are allowed briefly but heat the fuse, FET and copper.

Warning. Lithium-ion packs can deliver hundreds of amps into a short circuit. Fit the fuses before connecting a pack, keep loose metal away from the XT60 pins, and never bridge the two battery inputs. The board does not charge, balance or disconnect packs. Unplug packs for storage: each pack drains about 0.32 mA while plugged in with the host off, which empties a 5 Ah pack at 10 % charge in about 65 days.

8. Mechanical

Parameter	Value
Board size	64.0 x 62.0 mm, 3 mm corner radius
Thickness	1.6 mm FR-4, 2 layers, 1 oz copper both sides
Finish	Lead-free HASL, green solder mask, white silkscreen
Mounting holes	4 x 3.2 mm for M3, centres 3.0 mm from each edge (58.0 x 56.0 mm pattern), isolated from copper, 3.6 mm radius clear for screw heads
Component height, top	About 20 mm at the ATO fuses, 13 mm at the electrolytic capacitor, 8.5 mm at the XT60s
Component height, bottom	None. Through-hole leads protrude up to 1.5 mm.
Connector overhang	BATT A and BATT B: 0.5 mm past the left edge. LOAD: 7.8 mm past the right edge. An enclosure needs cut-outs at both edges.
Mass	About 25 g with fuses (estimate)

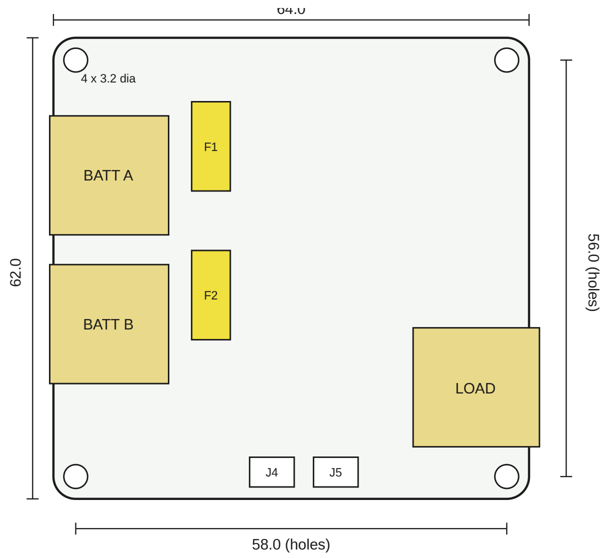

Figure 3. Outline, top view, millimetres. Connector body sizes are approximate; the LOAD nose overhang is not shown.

8.1 Connector positions

Board-local coordinates, origin at the top-left corner of the outline as viewed from the top, x to the right, y down.

Ref	Centre x (mm)	Centre y (mm)	Note
J1 BATT A	15.85	18.5	Pins on 7.2 mm pitch along y; face at the left edge
J2 BATT B	15.85	38.5	As J1, 20 mm below
J3 LOAD	56.45	47.0	Pins on 7.2 mm pitch along y; face at the right edge
J4 Qwiic	29.5	58.6	Opening at the bottom edge
J5 Qwiic	38.0	58.6	Opening at the bottom edge
F1, F2 fuses	21.2	14.9, 34.9	Blade slots along y
H1 to H4 holes	3.0, 61.0	3.0, 59.0	3.2 mm

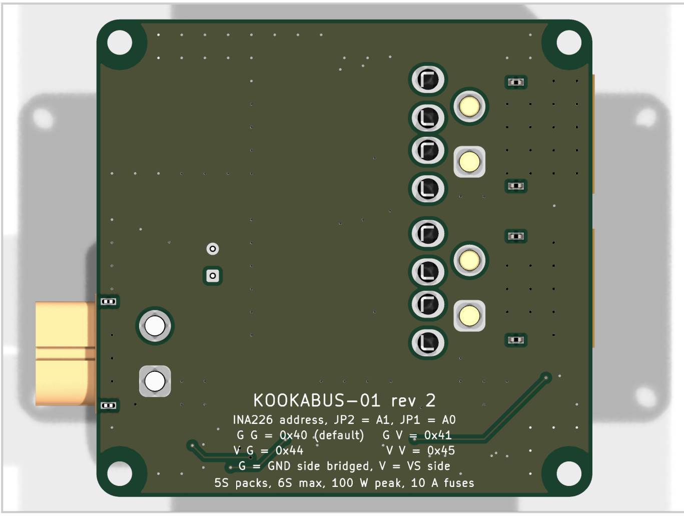

Figure 4. Bottom view. Ground plane, address table and the through-hole pins of the connectors, fuse holders and output capacitor.

9. Application information

9.1 Typical connection

1. Fit a 10 A ATO fuse in F1 and F2.
2. Connect the robot's power input to LOAD with a male XT60 lead.
3. Connect the host's Qwiic or PiicoDev port to J4 with a 4-way JST SH cable. Use J5 to chain further I2C boards.
4. Plug the first pack into BATT A. Its LED lights once the host's 3.3 V is present.
5. Plug the second pack into BATT B. To swap packs later, unplug the one whose LED is off, replace it, and repeat for the other. The load never loses power as long as one pack stays connected.

9.2 Host firmware checklist

- Write CALIBRATION = 2048 at every start-up, and CONFIG = 0x4527 if averaging is wanted.
- Poll bus voltage and current at a few hertz. Stop the load, or warn, when bus voltage falls to the pack's minimum (about 15 V for a 5S pack, 3.0 V per cell).
- Detect a swap as a step in bus voltage. The higher-voltage pack always carries the load, so the voltage reading always describes the pack in use.
- Disable regenerative braking in the motor controllers, or fit a brake resistor on the load side.

9.3 Using the board without a host

The hot swap works with nothing connected to J4 or J5. Only the LEDs and the I2C reading need the host's 3.3 V. For a bench check, any Qwiic host or a 3.3 V supply on pin 2 of J4 lights the LED of the conducting pack.

9.4 Thermal

At 40 W continuous the board dissipates about 0.18 W and barely warms. At the 100 W peak the pass FET of the conducting pack dissipates up to 0.47 W and rises about 30 °C above ambient in still air; the fuse and shunt each add about 0.3 W. No heatsink is required for the rated duty. Sustained operation above 7 A is outside the rating.

10. Ordering and fabrication

Item	Detail
Product	Kookabus-01, board revision 2
Supplied as	Assembled board without fuses, or bare PCB with the design files
Fuses required	2 x ATO/ATC 10 A 32 V blade fuse
Design files	KiCad 10 project, Gerbers, drill, position and BOM files, JLCPCB assembly BOM and placement files
Key components	2 x MX74700T ideal-diode controller (TI LM74700-Q1 compatible), 2 x AO4262E 60 V FET, INA226AIDGSR monitor, 5 mOhm 2512 shunt, MCP6002 comparator, SMBJ33CA and SMBJ26A TVS, PESD5V0S2BT ESD, XT60PW connectors, XF-507P fuse holders

11. Revision history

Board rev	Date	Change
1	24 September 2026	First design: 30 A continuous, INA228, on-board 3.3 V regulator, 2 oz copper.
2	25 September 2026	Re-rated to 100 W peak and 40 W continuous for low cost and hand assembly. INA226, MX74700T, AO4262E, 5 mOhm shunt, 10 A blade fuses, no on-board regulator (3.3 V from the host), 1 oz copper, 64 x 62 mm. Named Kookabus-01.

Document rev	Date	Change
1.0	25 September 2026	First release, for board revision 2. Preliminary: calculated values, not yet measured on hardware.