Protection against voltage spikes, generated by the pump electric start system, has been achieved (perhaps with an element of overkill) by applying a protection strategy (assisted by ChatGPT model 4.5) to each key component of the shed and house systems after identifying component-specific surge and spike protection mechanisms.

1. House Cupboard System

Raspberry Pi 4

- Requires stable, noise-free 5V power supply. Should not share power with any switching loads like relays. Setup:
- With Arduinos 1 & 2 use a single LM2596 buck converter rated at 5V, 3A
- Output filtering with 470 µF electrolytic + 0.1 µF ceramic capacitor
- TVS diode (P6KE6.8A) across 5V and GND near Raspberry Pi input
- Ferrite bead on 5V line to suppress EMI
- Keep GND isolated from relay ground until battery terminal

Latch Relays (x2)

- These require brief 5V pulses to actuate. Should be isolated from sensitive logic devices. Setup:
- Use a second LM2596 buck converter rated at 5V, 2A
- 470 µF + 0.1 µF output capacitors
- TVS diode (P6KE6.8A) on output
- Ferrite bead on output line if wiring is long
- GND returns directly to battery terminal via shared GND point

Arduino 1 and Arduino 2

- 220–470 Ω series resistor on each GPIO connected to multicore cable
- P6KE6.8A TVS diode between each GPIO and GND
- 0.1 µF ceramic capacitor from each GPIO to GND
- Share LM2596 with Raspberry Pi

RS485 Module

- 120 Ω termination resistor between A and B lines
- TVS diode (SMBJ6.0CA) across A/B to GND
- 0.1 µF + 470 µF capacitors on VCC

Buck Converter (12V → 5V)

- 470 µF electrolytic + 0.1 µF ceramic capacitors on output
- Ferrite bead on output
- TVS diode (P6KE15A or 1.5KE18A) on input

RS485 Line Protection

- Twisted pair within 13-core cable
- Ferrite core clamp on A/B at entry
- Shield grounded at House end only

2. Shed System

Arduino 3

- 220–470 Ω series resistor on each sensor pin
- P6KE6.8A TVS diode between pin and GND
- 0.1 µF ceramic capacitor per input, close to Arduino

8-Channel Relay Strip (Songle)

- Remove JD-VCC jumper to separate coil and logic power supply
- 1N4007 flyback diodes across relay coils
- MOV (V275LA20A) or TVS (1.5KE18A) across relay loads
- RC snubber (100Ω + 0.1 µF) across contacts
- 470 µF + 0.1 µF capacitors on JD-VCC input
- Ferrite bead on JD-VCC

Buck Converters

- Buck 1 (Relays): 470 µF + 0.1 µF + Ferrite + TVS on output
- Buck 2 (Logic): Same as above

Battery

- TVS diode (P6KE15A) across battery terminals
- Inline 10A blade fuse to shed wiring
- 12 AWG ground backbone
- Separate GND paths for power and logic until battery terminal

RS485 Module

- 120 Ω terminator between A/B
- TVS across A/B to GND
- Capacitor filtering on VCC

System-Wide Summary Table

Component	Location	Quantity
LM2596 Buck Converter Non-LM2596 Buck Converter	5V 3A adjustable step-down (1x House, 2x Shed) 1 x House (relays)	3
Electrolytic Capacitor	470 µF, 25V	10+
Ceramic Capacitor	0.1 µF, 50V	10+
TVS Diode	P6KE6.8A (5V protection)	12+

TVS Diode	P6KE15A or 1.5KE18A (12V protection)	5+
TVS Diode	SMBJ6.0CA (RS485 protection)	4
Ferrite Bead	Clip-on or inline, suitable for 5V/12V	6–8
Resistors	220–470 Ω, 0.25W	10+
Flyback Diode	1N4007 or equivalent	8
MOV	V275LA20A or similar	4
RC Snubber	100Ω + 0.1 µF (in series)	Optional (4 sets)
Fuse	10A automotive blade fuse	2
Relay Board	Songle SRD-05VDC-SL-C, 8 channels	1 (Shed)
Latch Relay	5V bistable relay	2 (House)
Raspberry Pi 4	Model B, 2–4 GB	1
RS485 Module	TTL to RS485 module (e.g., MAX485)	2
Shielded Cable	2–3 core, twisted pair	As required
Ground Wire	12 AWG stranded copper	Sufficient length for grounding backbone
Ferrite Core Clamp	For RS485 cable entry	2
Termination Resistor	120 Ω	2
Buck Converter (Non-LM2596, 330 Inductor)	1.5–2A step-down, used only for latch relays with added protection	1 (House only)
Schottky Diode	1N5819 for shared output lines	6+
Buffer IC	74HC125 or 74HC14 (optional for sensor inputs)	2
TVS Diode (shared lines)	SMBJ6.0CA or P6KE6.8A	6+
Ferrite Clamp	Clamp-on ferrite for multicore cable	2