A Universal Part Library Scheme for Makerspaces

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Abstract

Makerspaces, Fab Labs, and Tinker Labs around the world stock thousands of components- electronic, mechanical, consumable, and equipment- yet lack a common language for identifying and referencing those parts. Each institution relies on a patchwork of manufacturer part numbers, distributor SKUs, or internal codes that are mutually unintelligible, impeding design sharing, inventory management, and cross-institutional collaboration. This paper presents a Universal Part Library Scheme (UPLS) developed by the Zero2Maker initiative as an open-source, hierarchical, human-readable standard for categorizing and identifying makerspace components. The scheme uses a structured code format (Category–Subcategory–Sequential Number–Minor Type) covering electronic devices, electronic modules, mechanical parts, mechanical modules, tools, equipment, consumables, and kits. A reference implementation containing over 200 cataloged parts is described, along with a crowd-sourced governance model for ongoing expansion and verification. We argue that widespread adoption of a common part-Library standard would dramatically improve interoperability among makerspaces, reduce procurement friction, and accelerate the sharing of open-source hardware designs within the academic maker community.

1. Introduction

The global makerspace ecosystem has expanded rapidly over the past decade. Universities, polytechnics, community centers, and secondary schools now operate thousands of Fab Labs, Tinker Labs, and maker studios that collectively serve millions of students and independent creators. These spaces share a common purpose, enabling hands-on learning, rapid prototyping, and open innovation, yet they remain largely fragmented in how they organize, catalog, and communicate about the materials they stock.

A typical academic makerspace stocks a heterogeneous inventory that spans multiple domains: passive electronic components (resistors, capacitors, inductors), discrete and integrated semiconductors (diodes, transistors, microcontrollers), electronic modules (sensor boards, communication modules, motor drivers), mechanical hardware (screws, nuts, standoffs, wheels), power tools, hand tools, and consumables ranging from 3D printer filament to solder and adhesive tape. Managing this diversity is challenging enough within a single institution. Across institutions, the challenge is compounded by the absence of any shared vocabulary.

Today, a makerspace educator at University A who designs a robotics kit must describe its bill of materials using manufacturer part numbers (e.g., Texas Instruments TL071, Analog Devices AD8226) or distributor SKUs (e.g., DigiKey 296-6537-5-ND). A colleague at University B attempting to replicate that design faces multiple hurdles: manufacturer part numbers are proprietary, they encode no human-readable meaning, and they do not convey cross-manufacturer equivalence. Distributor SKUs are even less portable; they bind the buyer to a single vendor and often a single sourcing region.

The result is that despite the open-source ethos that pervades the maker community, designs and curricula remain difficult to replicate faithfully across institutions. Instructors re-specify components from scratch. Students cannot leverage existing designs. Administrators struggle to compare inventory across campuses. These inefficiencies impose real costs in time, money, and missed learning opportunities.

This paper proposes a remedy: a Universal Part Library Scheme (UPLS) designed specifically for the academic makerspace context. The scheme is open-source, hierarchical, manufacturer-agnostic, and extensible through a crowd-sourced governance model. We describe the structure of the scheme, its taxonomy of part categories, an existing reference database of over 200 parts developed by the Zero2Maker initiative, and the ecosystem of benefits that adoption would unlock.

2. Background and Related Work

2.1 Existing Part Library Practices in Makerspaces

Part numbering in commercial electronics manufacturing is a solved problem. Standards such as IPC-2575 (Heterogeneous Integration Roadmap) and EIA-481 address component packaging and tape-and-reel specifications. Large manufacturers maintain internal part number systems that encode product families, package types, and performance grades. Distributors such as DigiKey, Mouser, and RS Components assign their own SKUs that map to manufacturer part numbers.

None of these systems was designed for the makerspace context. Commercial part numbers prioritize supply-chain efficiency over human readability or cross-manufacturer equivalence mapping. A makerspace, by contrast, needs a part numbering system that: (1) is immediately meaningful to a non-specialist student who reads a bin label; (2) abstracts away from a specific manufacturer so that equivalent parts from any supplier can substitute; (3) spans both electronic and mechanical domains under a single taxonomy; and (4) supports the creation of kit-level part numbers that bundle component lists.

2.2 Existing Open-Source Hardware Catalogs

The open-source hardware movement has produced several component databases, including Open Parts Library (OPL) maintained by Seeed Studio, the KiCad component library, and Octopart's aggregated component search. These resources are valuable for electronic design automation

(EDA) but are not suited to makerspace inventory management: they are oriented toward PCB design rather than physical stock management, they do not span mechanical and consumable categories, and they provide no governance model for community-maintained equivalence mapping.

The UPLS described in this paper fills this gap by addressing physical inventory management across all makerspace material categories and providing a structured governance model for community contributions.

3. The Problem in Detail

3.1 The Manufacturer Part Number Trap

When a makerspace labels its component bins with manufacturer part numbers, it creates a subtle but significant lock-in. A bin labeled "TL071" implies that only the Texas Instruments TL071 operational amplifier is acceptable, even though Analog Devices, STMicroelectronics, and others produce functionally equivalent devices under different designations. A student reordering stock will search specifically for "TL071" and miss lower-cost or more locally available alternatives. A collaborating institution in another region may find the TI component unavailable and fail to realize that a readily available local equivalent would serve equally well.

This lock-in effect is not hypothetical. Informal surveys of academic makerspaces reveal that component reordering decisions are frequently constrained by the label on the bin rather than by any engineering considerations. The result is higher procurement costs, unnecessary supply-chain fragility, and missed learning opportunities regarding component equivalence, an important engineering concept.

3.2 The Distributor SKU Problem

Distributor SKUs are even more restrictive than manufacturer part numbers. A DigiKey SKU can only be ordered through DigiKey; it provides no path to alternative distributors or local suppliers. For academic institutions in regions where DigiKey does not operate, or for makerspaces with small budgets that benefit from local sourcing, distributor-specific numbering is actively harmful.

3.3 Internal Part Numbers Do Not Travel

Some larger makerspaces have created internal part numbering systems, essentially proprietary databases that assign local identifiers to each stocked item. These systems solve the inventory management problem within one institution, but they create a new barrier to collaboration. When an instructor shares a design, the internal part numbers are meaningless to any other institution. The receiving makerspace must manually decode each component reference, match it to a manufacturer part, and re-enter it into its own system.

3.4 The Design Sharing Bottleneck

The inability to share part numbers is, at root, an inability to share designs. Open-source hardware projects depend on unambiguous bill-of-materials specifications. The Arduino ecosystem succeeded in part because its component list is small, well-known, and globally available. More complex maker projects, such as robotics kits, environmental monitoring systems, CNC machines, require dozens or hundreds of components, and the friction of re-specifying those components for each new institution represents a significant drag on the dissemination of maker pedagogy.

4. The Universal Part Library Scheme

4.1 Design Principles

The UPLS was designed to satisfy the following requirements:

- Human readability: A part number should convey immediate, meaningful information about the component category without requiring a lookup.
- Manufacturer agnosticism: The part number must not encode any manufacturer identity, allowing any compatible component to be assigned the same identifier.
- Cross-domain coverage: A single scheme must span electronic, mechanical, consumable, tool, equipment, and kit categories.
- Extensibility: The scheme must accommodate new part categories and new parts within existing categories without restructuring.
- Kit composability: The scheme must support creating kit-level part numbers that reference individual component part numbers and quantities.
- Open governance: The scheme and its associated database must be open-source, with a defined process for community contributions and verification.

4.2 Code Structure

Every part number in the UPLS follows the format:

AAB-NNNNN-ZZZZZ

Where the fields are defined as follows:

Field	Length / Example	Description
AA	2 alpha / "EM"	Primary category (e.g., EM = Electronic Module, ED = Electronic Device, MM = Mechanical Module, TL = Tool, EQ = Equipment, CO = Consumable, KT = Kit)
B	1 alpha / "S"	Subcategory within the primary category (e.g., S = Sensor, A = Actuator, C = Communication, R = Resistors, M = Mechanical connectors)
NNNNN	5 digit / "00001"	Zero-padded sequential number assigned in order of addition to the database. Running number with no semantic meaning.

ZZZZZ	1 to 5 alphanumeric / eg.,"A" or 20K0	Minor type suffix, used to distinguish the same component in different colors, sizes, or packaging variants (A, B, C, ...). it may also be used to specifying resistor or capacitor value

For example, the part number EMS-00005-A decodes as: EM (Electronic Module) + S (Sensor subcategory) + 00005 (fifth sensor module added to the database) + A (first/only variant/value). This immediately communicates to any reader that the component is an electronic sensor module, without binding it to any specific manufacturer.

The part number EDR-00001-680Z stands for an ED (Electronic Device) + R (Resistor) + 00001 (0.25W carbon resistor with axial lead, 5% tolerance) + 680Z (680 Ohms. The letter shows the exponent Z or Ohm, K or Kilo Ohm, M or Meg Ohm)

4.3 Category Taxonomy

The UPLS defines six primary categories covering the full range of typical makerspace inventory:

Code	Category	Subcategories
EM	Electronic & Electrical Modules	EMP (Power), EMS (Sensors/Input), EMA (Actuators/Output), EMC (Communication), EMX (Controllers), EMK (Kits)
ED	Electronic Devices	EDS (Integrated Semiconductors), EDD (Discrete Semiconductors), EDR (Resistors), EDC (Capacitors), EDL (Inductors/Coils), EDT (Transducers), EDM (Mechanical: connectors, switches), EDK (Kits)
MM	Mechanical Modules	MMM (Mechanical Subassemblies), MMD (Mechanical Devices: motors, servos), MMC (Connect Assemblies), MMP (Mechanical Parts: screws, nuts), MMB (Containers), MMK (Kits)
TL	Tools	TLP (Power Tools), TLM (Hand Tools), TLC (Craft Tools), TLK (Kits)
EQ	Equipment & Instruments	EQM (Machines: 3D printers, laser cutters, CNC), EQE (Instruments: oscilloscopes, multimeters)
CO	Consumables	COC (Craft Materials: filament, solder, adhesives, wires), COS (Stationery), COE (Batteries & Cells), COK (Kits)
KT	Combined Kits	Curated kits
FP	Fabricated Parts	FPA (Assembly) FPM (Mechanical) FPE (Electrical) FPS (Software)

4.4 Kit Part Numbers

One of the most powerful features of the UPLS is the ability to define kit-level part numbers. A kit part number (e.g., EMK-001-A or MMK-001-A) does not correspond to a single physical component but to a curated collection of individually numbered parts, each with a specified quantity.

This allows a makerspace to define, for example, a "Z2M Starter Kit Box" (EMK-001-A) containing 29 different sensor and communication modules at specified quantities, or a "DPDT RJ12 Robotic Car" kit (MMK-001-A) containing 15 different components. An instructor sharing a curriculum can reference a single kit part number; the recipient can look up the full bill of materials, identify equivalent parts from local suppliers, and assemble an identical kit.

Kit part numbers also enable efficient inventory tracking: a single scan of the kit QR code reveals not only the kit contents but the individual part numbers of every included component, each of which links to its own information page.

5. Reference Implementation: The Universal Parts Library

5.1 Database Overview

The Zero2Maker initiative has developed a reference implementation of the UPLS containing over 200 cataloged parts spanning all primary categories. Table 3 summarizes the current distribution across categories.

Category	Example Parts in Reference Database	Sample Parts
Electronic Modules (EM)	Sensors, actuators, communication, power, controllers	Ultrasonic sensor, I2C LCD, GPS module, Bluetooth HC-05
Electronic Devices (ED)	Passives, semiconductors, connectors, switches	Resistors, capacitors, LEDs, transistors, analog/digital chips
Mechanical Modules (MM)	Motors, servos, wheels, fasteners	DC gearmotor, SG90 servo, M3 screws, brass standoffs
Tools (TL)	Power tools, hand tools, craft tools, kits	Soldering iron, hacksaw, cutting mat, steel ruler
Equipment (EQ)	Machines and instruments	3D printer, laser cutter, oscilloscope, multimeter
Consumables (CO)	3D filament, solder, tape, batteries, stationery	PLA filament (1.75mm & 2.85mm), AA batteries, hot glue
Kits (KT)	Curated component sets	Starter kit, Robotic Car kit, Bill of Materials
Fabricated Parts (FP)	Custom assemblies with mech, electrical, coding	Finished product designs shared to be fabricated by anyone

5.2 Per-Part Information Record

Each part number in the UPLS database is associated with a structured information record containing:

- Part number and human-readable name
- Category and subcategory classification

- Brief description and key specifications
- Product image (for visual identification in a stockroom)
- Datasheet link (manufacturer's technical specification)
- Application notes and usage examples
- Search keywords
- Multiple manufacturer entries: brand name, manufacturer part number, and link to manufacturer page
- Multiple vendor entries: distributor name and link to product listing
- QR code linking to the full online record

This rich per-part record transforms the part number from a mere identifier into a gateway to all information a maker needs: technical specifications, purchasing options, and usage guidance. Critically, multiple manufacturer entries for the same part number explicitly indicate equivalence; a student reading the record immediately sees all compatible parts from different manufacturers and can choose based on local availability and cost.

5.3 Physical Implementation: QR-Code Bin Labels

The UPLS is designed to integrate directly with physical stockroom management. Each storage bin carries a label displaying the part number, a brief one-line description, and a QR code that links to the part's online information record. A student unfamiliar with a component can scan the QR code and, within seconds, access the full technical record: what the part is, what it does, its specifications, and where to buy it.

This approach eliminates the need for staff intervention in the most common stockroom inquiry ("what is this part and what can I do with it?") and transforms the physical stockroom into a self-documenting learning resource.

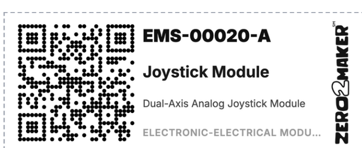

Fig 1. Sample of a bin label on the stock shelf

6. Crowd-Sourced Governance Model

6.1 Rationale

A universal part library scheme is only as useful as its coverage. No single institution can catalog every component used across the global makerspace community. The UPLS therefore adopts an open, crowd-sourced governance model analogous to those used by successful open-source projects such as Wikipedia and open-hardware repositories.

6.2 Part Submission Process

Any maker, educator, or institution can request that a new part be added to the UPLS database. The submission process requires:

- Identification of the appropriate category and subcategory
- Component name and brief description
- Link to a component image
- Link to a manufacturer’s datasheet
- Submitter contact information (optional, for acknowledgment and clarification)

Submitted parts enter a review queue where volunteer reviewers verify the category assignment, check for duplicate entries, identify equivalent parts already in the database, and confirm datasheet accuracy. Upon approval, a new part number is assigned, and the record is published to the global database.

6.3 Correction and Amendment

Errors in the database, such as incorrect specifications, broken datasheet links, and missing equivalents, can be flagged by any user. Flagged items are reviewed by the same volunteer board, corrected, and republished. This continuous correction mechanism keeps the database accurate as components evolve and datasheets are updated.

6.4 Equivalence Mapping

One of the most valuable governance activities is equivalence mapping: identifying that multiple manufacturer part numbers correspond to the same UPLS identifier. Volunteer reviewers with domain expertise can add manufacturer entries to existing records, building a growing equivalence graph that benefits all users. A single UPLS part number may ultimately map to dozens of manufacturer part numbers from suppliers around the world.

7. Ecosystem Benefits and Future Directions

7.1 Distributor Integration

The long-term vision for the UPLS includes an API that allows electronics distributors to associate their stock listings with UPLS part numbers. A distributor that carries three functionally equivalent op-amps from different manufacturers could tag all three with the same UPLS identifier. A makerspace user searching by UPLS number would then see real-time availability and pricing from multiple distributors, enabling one-click procurement of the best available option.

This integration would also benefit distributors: UPLS-aware users would be more likely to find and purchase products through distributor platforms, as the standard dramatically reduces search friction.

7.2 Curriculum and Design Portability

Academic makerspaces increasingly share curricula, project templates, and instructional materials. The UPLS provides the missing layer that makes these materials fully portable: a bill of materials specified in UPLS part numbers is interpretable by any institution that uses the scheme, and the associated equivalence records ensure that locally available substitutes can be identified immediately.

Competitions, hackathons, and collaborative research projects between institutions would benefit similarly. Teams using a shared vocabulary for parts can collaborate more effectively than teams that must first harmonize their component catalogs.

7.3 Inventory Management Integration

Inventory management software used by makerspaces (both commercial products and custom systems) could integrate UPLS as a standard identifier layer. Rather than each system maintaining its own internal part codes, all systems could share a common namespace, enabling cross-institutional inventory queries, loan programs, and demand aggregation for bulk purchasing.

7.4 Pedagogical Value

Beyond logistics, the UPLS has direct pedagogical value. The hierarchical taxonomy embodies an engineering classification scheme that students encounter in professional practice. Learning to navigate a structured parts database is itself a transferable skill. The explicit representation of component equivalence teaches the important engineering concept that functional specifications matter more than brand names, a lesson that naive reliance on manufacturer part numbers obscures.

8. Proposed Adoption Strategy

We propose a phased adoption strategy for the UPLS within the academic makerspace community:

Phase 1: Institutional Piloting: Three to five academic makerspaces adopt the UPLS for their inventory labeling. Physical bin labels with QR codes are implemented. Feedback on taxonomy coverage and usability is collected.

Phase 2: Database Expansion: The crowdsourced submission process is opened to the public. Participating institutions contribute parts specific to their regional supply chains, expanding global coverage. The governance board is formalized with representation from multiple institutions.

Phase 3: Curriculum Integration: Participating institutions begin specifying shared curricula and project templates using UPLS part numbers. A shared repository of UPLS-specified maker project designs is established.

Phase 4: Distributor Engagement: The API specification for distributor integration is published. Pilot integrations with regional electronics distributors are established, beginning with distributors that already serve academic customers.

Phase 5: Standard Recognition: The UPLS is submitted to relevant standards bodies (e.g., IEEE, IPC, or FabLab's own standards committee) for recognition as a community standard for academic makerspace part library.

Conclusion

The absence of a common part numbering standard is a quiet but significant barrier to collaboration within the academic makerspace community. It forces unnecessary duplication of effort, constrains purchasing to specific manufacturers and distributors, and prevents the full realization of the open-source hardware ideal that makerspaces espouse.

The Universal Part Library Scheme presented in this paper offers a practical, open-source remedy. Its hierarchical taxonomy covers the full range of makerspace inventory. Its manufacturer-agnostic identifiers liberate procurement from brand lock-in. Its crowd-sourced governance model ensures living coverage as the maker ecosystem evolves. And its physical QR code implementation transforms stockroom bins into self-documenting learning resources.

We invite the FabLab community to evaluate the scheme, pilot its adoption, and contribute to its governance. The benefits for inventory management, design sharing, curriculum portability, and maker education are substantial. The cost of adoption is low: a taxonomy, a database, and a commitment to a common vocabulary.

The maker community has demonstrated repeatedly its capacity for open collaboration. A universal part library scheme is one more opportunity to build shared infrastructure that serves all.

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