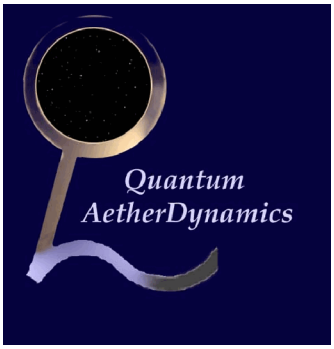

Quantum AetherDynamics Institute (QADI)

A Ledger Formulation of Impedance: Eliminating Imaginary Numbers Through Quantum Measurement Units

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Abstract

Electrical impedance is traditionally represented as a complex quantity composed of resistance and reactance. The conventional formulation assigns both quantities the unit ohm and combines them through the imaginary operator j. This paper argues that the use of imaginary numbers in impedance theory arises from dimensional compression inherited from SI/MKS conventions. Using Quantum Measurement Units (QMU), resistance and magnetic flux occupy distinct dimensional positions within a unified ledger. A ledger formulation of impedance is developed in which the dimensional distinction remains explicit and no imaginary operator is required.

Keywords: Quantum Measurement Units; QMU; impedance; reactance; resistance; magnetic flux; conductance; admittance; dimensional analysis; Aether Physics Model

1 Introduction

Classical alternating-current theory Steinmetz [1900], Orloff [2024] represents impedance as

$$Z = R + jX. \tag{1}$$

The imaginary operator j distinguishes reactive behavior from dissipative behavior while preserving a common unit assignment.

This treatment is mathematically successful for engineering calculations. However, it conceals the dimensional distinction between resistance and magnetic-flux behavior.

The purpose of this paper is to examine impedance from the perspective of Quantum Measurement Units (QMU) Thomson III [2025e,c], where resistance and magnetic flux remain separate dimensional objects.

A complete operational implementation of the ledger formulation is developed in companion work Thomson III [2026, 2025b]. There, alternating-current systems are represented using purely real (2×2) rotation–scaling matrices and ledger-preserving transformations. The present paper focuses on the dimensional interpretation underlying that construction and the reasons the conventional complex-plane representation arises.

2 Ledger Separation of Resistance, Magnetic Flux, Conductance, and Admittance

QMU defines resistance Thomson III [2025e,d] as

$$resn = \frac{m_{\mathrm{e}} {\lambda_C}^2 F_q}{{e_{\mathrm{emax}}}^4}. \tag{2}$$

QMU defines magnetic flux Thomson III [2025e,d] as

$$mflx = \frac{m_{\mathrm{e}} {\lambda_C}^2 F_q}{{e_{\mathrm{emax}}}^2}. \tag{3}$$

Both quantities share the same mechanical numerator,

$$m_{\mathrm{e}}{\lambda_C}^2 F_q, \tag{4}$$

but differ by one magnetic-charge rank. Therefore,

$$resn = \frac{mflx}{{e_{\mathrm{emax}}}^2}, \qquad mflx = resn \cdot {e_{\mathrm{emax}}}^2. \tag{5}$$

Resistance and magnetic flux are therefore not the same dimensional object in the QMU ledger. Their distinction is not numerical; it is dimensional.

The reciprocal of resistance is admittance,

$$admt = \frac{1}{resn}, \tag{6}$$

while the reciprocal of magnetic flux is conductance,

$$cond = \frac{1}{mflx}. \tag{7}$$

Since

$$mflx = resn \cdot {e_{\mathrm{emax}}}^2, \tag{8}$$

their reciprocals satisfy

$$cond = \frac{admt}{{e_{\mathrm{emax}}}^2}. \tag{9}$$

QMU therefore distinguishes four separate ledger quantities:

$$resn, \qquad mflx, \qquad admt, \qquad cond. \tag{10}$$

These form two reciprocal pairs:

$$resn \leftrightarrow admt, \qquad mflx \leftrightarrow cond. \tag{11}$$

Conventional electrical theory compresses this structure. Resistance and reactance are both assigned the unit ohm, while conductance and admittance are both assigned the unit siemens Newell and Tiesinga [2019], Bureau International des Poids et Mesures [2019]. The conventional framework is numerically successful because it supports practical circuit calculation, but it does not preserve the magnetic-charge rank separating dissipative and stored-field behavior.

The QMU ledger retains the separate dimensional identities of resistance, magnetic flux, admittance, and conductance while preserving their reciprocal relationships.

Table 1: Conventional and QMU Electrical Quantities

Conventional Quantity	Conventional Unit	QMU Quantity
Resistance	Ohm	$resn$
Reactance	Ohm	$mflx$
Admittance	Siemens	$admt$
Conductance	Siemens	$cond$

3 Reactance as Projected Magnetic Flux

The conventional definitions of reactance are

$$X_L = \omega L \tag{12}$$

for inductive systems and

$$X_C = -\frac{1}{\omega C} \tag{13}$$

for capacitive systems.

Both expressions are assigned the conventional unit ohm, even though they describe stored-field behavior rather than dissipation Orloff [2024].

In the QMU ledger, the reactive component is represented by a magnetic-flux quantity. Let this stored-field component be denoted by Φ, where

$$\Phi \in mflx. \tag{14}$$

Since

$$mflx = resn \cdot {e_{\text{emax}}}^2, \tag{15}$$

a magnetic-flux quantity may be projected into the conventional resistance axis through

$$X = \frac{\Phi}{{e_{\text{emax}}}^2}. \tag{16}$$

Equivalently, the magnetic-flux component corresponding to a conventional reactance is

$$\Phi = {e_{\text{emax}}}^2 X. \tag{17}$$

For an inductor,

$$\Phi_L = {e_{\text{emax}}}^2 \cdot \omega L. \tag{18}$$

For a capacitor,

$$\Phi_C = -{e_{\text{emax}}}^2 \frac{1}{\omega C}. \tag{19}$$

The positive sign of Φ_L and the negative sign of Φ_C preserve the conventional distinction between inductive and capacitive reactance.

Reactance therefore appears in conventional AC theory as a resistance-axis projection of an underlying magnetic-flux component. The stored-field component itself belongs to $mflx$, while its projected value belongs to $resn$. This explains why conventional reactance can be added to resistance only after dimensional compression.

The conventional impedance equation

$$Z = R + jX \tag{20}$$

may therefore be interpreted as a projection of distinct QMU ledger quantities into a common algebraic representation. The imaginary operator j preserves the distinction operationally, while the dimensional separation itself is hidden by the conventional unit assignment. “‘

“‘latex

4 Ledger Impedance and the Role of Complex Numbers

The present argument is not a rejection of complex-number methods. Complex impedance has been extraordinarily successful Steinmetz [1900], Orloff [2024] because it preserves two independent aspects of electrical behavior within a single algebraic object.

In conventional alternating-current theory,

$$Z = R + jX, \tag{21}$$

the resistance term represents dissipative behavior, while the reactance term represents stored-field behavior. The imaginary operator allows both quantities to coexist in a common mathematical framework without becoming numerically indistinguishable.

The QMU ledger reaches the same structural conclusion, but places the separation in dimensional rank rather than in the complex plane. Impedance may be represented as the ordered pair

$$\mathcal{Z} = (R, \Phi), \tag{22}$$

where

$$R \in resn, \qquad \Phi \in mflx. \tag{23}$$

The first component represents dissipative behavior. The second component represents stored-field behavior. No dimensional collapse occurs, because both quantities retain their native ledger identities.

Since

$$mflx = resn \cdot {e_{\text{emax}}}^2, \tag{24}$$

the magnetic-flux component may be projected into the resistance domain through

$$X = \frac{\Phi}{{e_{\text{emax}}}^2}. \tag{25}$$

The conventional impedance equation therefore corresponds to the ledger representation

$$Z = R + jX \qquad \longleftrightarrow \qquad \mathcal{Z} = (R, \Phi), \qquad X = \frac{\Phi}{{e_{\text{emax}}}^2}. \tag{26}$$

Complex numbers preserve the distinction algebraically. The QMU ledger preserves the distinction dimensionally. Both approaches maintain the separation between dissipative and reactive behavior; the difference lies in where that separation is encoded.

In conventional theory, the distinction is embedded in the imaginary axis. In QMU, it is embedded in magnetic-charge rank and dimensional structure.

4.1 Ledger Arithmetic

Within the ledger formulation, impedance components retain their dimensional identities and combine component-wise. For example, series impedances satisfy

$$\mathcal{Z}_{\text{tot}} = (R_1, \Phi_1) + (R_2, \Phi_2) = (R_1 + R_2, , \Phi_1 + \Phi_2). \tag{27}$$

The resulting structure preserves the separation between dissipative and stored-field behavior throughout the calculation. More general network reductions may be performed either through projection into the conventional impedance domain or through the purely real matrix methods developed in the companion operational formulation Thomson III [2026, 2025b].

5 Recovery of Conventional Magnitude and Phase

A useful ledger formulation must reproduce the results of conventional alternating-current analysis. The QMU impedance pair

$$\mathcal{Z} = (R, \Phi) \tag{28}$$

contains both the dissipative and stored-field components of the circuit. Projection into the resistance domain gives

$$X = \frac{\Phi}{{e_{\text{emax}}}^2}. \tag{29}$$

The impedance magnitude becomes

$$|\mathcal{Z}| = \sqrt{R^2 + \left(\frac{\Phi}{{e_{\text{emax}}}^2}\right)^2}. \tag{30}$$

This is identical to the conventional result

$$|Z| = \sqrt{R^2 + X^2}. \tag{31}$$

Consequently, current magnitude is preserved:

$$I = \frac{V}{|\mathcal{Z}|} = \frac{V}{\sqrt{R^2 + \left(\frac{\Phi}{{e_{\text{emax}}}^2}\right)^2}}. \tag{32}$$

The conventional phase angle is also recovered:

$$\theta = \tan^{-1}\left(\frac{X}{R}\right) = \tan^{-1}\left(\frac{\Phi/{e_{\text{emax}}}^2}{R}\right). \tag{33}$$

The ledger formulation therefore does not eliminate phase. It separates dimensional bookkeeping from phase bookkeeping. Phase remains a geometric relationship between the stored-field and dissipative components after projection into a common comparison domain.

As a simple example, the conventional series RL impedance

$$Z = R + j\omega L \tag{34}$$

corresponds to the ledger pair

$$\mathcal{Z}_{RL} = (R, \Phi_L), \tag{35}$$

where

$$\Phi_L = {e_{\text{emax}}}^2 \cdot \omega L. \tag{36}$$

Substitution gives

$$|\mathcal{Z}_{RL}| = \sqrt{R^2 + \left(\frac{\Phi_L}{{e_{\text{emax}}}^2}\right)^2} = \sqrt{R^2 + (\omega L)^2}. \tag{37}$$

This is the conventional RL impedance magnitude Thomson III [2026, 2025b]. The ledger representation therefore preserves standard AC predictions while retaining the dimensional distinction between resistance and magnetic flux. “‘

6 Discussion

The conventional impedance equation remains useful for engineering calculations.

However, its use of imaginary numbers obscures the underlying dimensional relationship between resistance and magnetic flux.

QMU reveals that these quantities differ by a magnetic-charge rank and therefore occupy separate positions within the dimensional ledger.

The resulting framework suggests that impedance may be reformulated without imaginary numbers while preserving the physical distinction between dissipative and reactive behavior.

7 Falsifiability and Experimental Consequences

The ledger formulation presented here is not merely a reinterpretation of existing notation. It makes specific claims that may be tested mathematically and experimentally Thomson III [2026, 2025b].

The central claim is that resistance and reactance correspond to distinct dimensional quantities within the QMU ledger:

$$R \in resn, \qquad \Phi \in mflx, \tag{38}$$

with the relationship

$$mflx = resn \cdot {e_{\max}}^2. \tag{39}$$

The validity of the ledger formulation therefore depends upon its ability to reproduce the predictions of conventional alternating-current theory while preserving this dimensional distinction.

The first falsification criterion is mathematical.

If a complete ledger algebra cannot reproduce the established results of phasor analysis, including impedance magnitude, phase angle, resonance conditions, series combinations, and parallel combinations, then the ledger interpretation must be regarded as incomplete or incorrect.

The second falsification criterion is dimensional.

The ledger formulation predicts that resistance, reactance, admittance, and conductance correspond to four distinct dimensional quantities:

$$resn, \qquad mflx, \qquad admt, \qquad cond. \tag{40}$$

If future dimensional analysis demonstrates that these quantities collapse into identical dimensional objects without loss of physical information, the principal motivation for the ledger framework would be removed.

The third falsification criterion is predictive.

The ledger formulation predicts that all conventional impedance relationships should be recoverable through dimensional projection from the ordered pair

$$\mathcal{Z} = (R, \Phi). \tag{41}$$

If electrical systems are discovered for which conventional complex impedance succeeds but no corresponding ledger representation exists, then the present formulation would be falsified.

Conversely, successful recovery of conventional AC results from a dimensional ledger would support the hypothesis that the imaginary operator functions primarily as a compact representation of independent dissipative and stored-field components rather than as a fundamental dimensional requirement.

Future work will extend the ledger framework to resonance, network analysis, power-factor calculations, and distributed electromagnetic systems in order to test these predictions quantitatively.

8 Conclusion

Quantum Measurement Units distinguish resistance and magnetic flux through magnetic-charge rank. As a consequence, the reactive and dissipative components of an electrical system occupy different dimensional positions within the QMU ledger.

The conventional impedance equation,

$$Z = R + jX, \tag{42}$$

may therefore be interpreted as a dimensional projection in which distinct ledger quantities are represented within a common algebraic framework. The imaginary operator successfully preserves the distinction operationally, but the dimensional separation itself is hidden.

The ledger formulation replaces this compression with the ordered pair

$$\mathcal{Z} = (R, \Phi), \tag{43}$$

where resistance and magnetic flux remain explicit dimensional quantities. Conventional impedance magnitude and phase relations are recovered through projection, demonstrating that the ledger representation reproduces standard alternating-current predictions while preserving dimensional structure.

The result suggests that imaginary numbers are not a fundamental requirement of impedance theory. Rather, they may be viewed as an efficient computational device for representing quantities whose dimensional distinction has been compressed by conventional unit systems. Future work will

extend the ledger framework to resonance, network synthesis, transmission systems, and distributed electrodynamics.

Acknowledgments

The Quantum AetherDynamics Institute (QADI) is a private 501(c)(3) research institute developing the Aether Physics Model (APM) and Quantum Measurement Units (QMU) Thomson III [2025a]. Publications and data are archived with DOIs in the AetherPhysics Zenodo community: zenodo.org/communities/aetherphysics.

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