

# Cost-Effective Ultrasonic Phased Array Elements for Custom Flaw Detection Systems

Building a custom ultrasonic phased array system for metal flaw detection requires careful consideration of sensor element costs while maintaining performance standards. Based on comprehensive market research, several affordable options exist for obtaining phased array elements that can serve as building blocks for custom non-destructive testing (NDT) systems, with prices ranging from as low as \$50 to several thousand dollars depending on specifications and supplier choice.

## Understanding Phased Array Technology for NDT Applications

Phased array ultrasonic testing (PAUT) represents a sophisticated approach to non-destructive testing that offers significant advantages over conventional ultrasonic methods. The technology involves multiple ultrasonic transducer elements within a single probe, each individually controlled to emit and receive ultrasonic waves<sup>[1]</sup>. By adjusting the timing of these waves through a process known as phasing, the ultrasonic beam can be steered and focused electronically without physical probe movement<sup>[1]</sup>. This capability enables detailed inspection of materials and detection of flaws such as cracks, voids, and inclusions with high accuracy<sup>[1]</sup>.

The fundamental principle underlying phased array systems relies on wave interference, which allows the shaping of ultrasound beams through controlled timing delays of each element's emitted sound pulse<sup>[2]</sup>. Phased array probes typically utilize piezocomposite elements rather than traditional piezoceramic elements, providing increased sensitivity of 10 to 30 dB relative to their piezoceramic counterparts<sup>[3]</sup>. These advanced transducers combine several tiny piezoelectric elements to generate multiple ultrasonic waves that analyze flaws within components, with signals controlled using computer programs to generate time-lagged and angled waves for accurate mapping during NDT applications<sup>[3]</sup>.

However, implementing phased array technology does present certain challenges. The systems require higher technical skill levels for operators to manage sophisticated beam steering and interpret detailed data<sup>[1]</sup>. Complex setup procedures can be intricate and time-consuming, while some materials or complex geometries may hinder ultrasonic beam performance<sup>[1]</sup>. Despite these considerations, the technology offers an impressive combination of precision and efficiency for industrial inspection applications<sup>[1]</sup>.

## Low-Cost Phased Array Element Options

## Entry-Level Commercial Elements

The most affordable option for obtaining phased array elements comes from NDT-KITS, which offers various transducer configurations at remarkably low prices. Their product line includes concave phased array transducers, linear small phased array transducers, TRL phased array transducers, wheel series phased array transducers, and flexible array series phased array transducers, all priced at \$50.00 each<sup>[3]</sup>. These elements represent an exceptional entry point for custom system development, though specific technical specifications are not detailed in their basic product listings.

For those requiring higher element counts, medical-grade 64-element phased array transducers are available for approximately \$6,309.30 USD<sup>[4]</sup>. These units operate at a central ultrasonic frequency of approximately 4 MHz with a frequency range of 1.5-5.0MHz and provide a 90-degree field of view<sup>[4]</sup>. While designed for medical applications such as cardiac and abdominal imaging, the underlying piezoelectric technology remains applicable to industrial NDT applications with appropriate signal processing modifications.

## DIY and Research Platform Approaches

Academic research has demonstrated that cost-effective phased array systems can be constructed using off-the-shelf components. A notable example is the underwater acoustic phased array research system developed at Harvey Mudd College, which achieved a total cost of only \$1,710 USD<sup>[5]</sup>. This low cost was accomplished by using commercially available piezoelectric transducers that were modified to increase power transfer between the transducer and the medium, combined with low-cost microcontrollers providing crucial analog functions including data sampling<sup>[5]</sup>.

The research platform utilized a channelized architecture for transmit and receive circuitry, allowing easy scaling to 16- or 25-element arrays<sup>[5]</sup>. The system demonstrated effective beam steering with transmit resolution of 1.8° and receive beam steering resolution of 0.5°<sup>[5]</sup>. While designed for underwater applications, the fundamental principles and component selection strategies are directly applicable to air-coupled or contact ultrasonic applications for metal inspection.

## Chinese Manufacturing Sources and Suppliers

### Piezoelectric Component Suppliers

Chinese manufacturers offer competitive pricing for individual piezoelectric elements that can serve as building blocks for custom phased array systems. Alibaba provides access to numerous suppliers offering PZT (lead

zirconate titanate) ceramic discs and sheets at various specifications<sup>[6][7]</sup>. These piezoelectric materials form the foundation of ultrasonic transducers and can be assembled into custom array configurations.

Specific examples include 10mm diameter, 5MHz PZT crystal piezo ceramic discs designed for ultrasonic sensors, available from suppliers like TAIMI with customizable specifications<sup>[8]</sup>. These discs feature resonant frequencies of  $5\text{MHz} \pm 3\%$ , relative dielectric constants of  $1500 \pm 15\%$ , and electrical-mechanical coupling coefficients  $\geq 0.6$ <sup>[8]</sup>. Such components typically require minimum orders of 1000 pieces but offer significant cost advantages for larger projects<sup>[8]</sup>.

For smaller quantities, mini piezo components are available starting at \$0.09-0.15 USD per piece with 100-piece minimum orders<sup>[7]</sup>. While these may not meet the exact specifications required for high-performance NDT applications, they demonstrate the cost-effectiveness achievable through Chinese manufacturing channels<sup>[7]</sup>.

## Professional NDT Equipment Suppliers

Chinese NDT equipment manufacturers like M2 Electronics (Shanghai) Co., Ltd. offer professionally manufactured phased array probes specifically designed for industrial applications<sup>[9]</sup>. Their product line includes various configurations ranging from \$1,880 to \$4,600 for complete probe assemblies<sup>[9]</sup>. While more expensive than individual elements, these products provide proven performance for weld inspection and other NDT applications<sup>[9]</sup>.

The company offers phased array transducers for composite channel inspections with shortened dead zones at both probe ends, priced between \$2,280-3,900<sup>[9]</sup>. For stainless steel weld applications, specialized ultrasound probes are available in the \$4,100-7,280 range<sup>[9]</sup>. These products represent middle-ground options between low-cost individual elements and expensive integrated systems from major manufacturers.

## Comparative Cost Analysis

### Element-Level Pricing

The most cost-effective approach involves sourcing individual piezoelectric elements and assembling them into custom arrays. Based on search results, pricing tiers include:

- Basic PZT ceramic discs: \$0.09-0.15 USD (100+ pieces)<sup>[7]</sup>
- Specialized 5MHz ultrasonic sensor discs: Negotiable pricing (1000+ pieces)<sup>[8]</sup>
- Professional phased array elements: \$50 USD each<sup>[3]</sup>

- Medical-grade 64-element arrays: \$6,309.30 USD complete<sup>[4]</sup>

## System-Level Considerations

When comparing costs, consider that major commercial phased array NDT systems can cost over \$100,000 USD. The Eddyfi Topaz 64 system with 64:128PR configuration including PAUT, UT, TOFD, and TFM capabilities is priced at \$125,655.00<sup>[10]</sup>. Even basic configurations start at \$107,115.00<sup>[10]</sup>, highlighting the significant cost savings potential of custom-built systems.

Research platforms demonstrate that functional phased array systems can be built for under \$2,000 using careful component selection and custom electronics design<sup>[5]</sup>. This represents a cost reduction of more than 50:1 compared to commercial systems while maintaining core functionality for many applications.

## Technical Considerations for Custom Implementation

### Element Specifications and Performance

When selecting individual elements for custom arrays, key specifications include resonant frequency, element size, bandwidth, and sensitivity. For metal flaw detection, frequencies between 2-10 MHz are typically appropriate, with 5MHz representing a common choice balancing penetration depth and resolution<sup>[4][8]</sup>. Element dimensions affect beam characteristics, with smaller elements providing wider beam patterns but potentially reduced sensitivity.

Piezocomposite materials generally offer superior performance compared to pure ceramic elements, providing better sensitivity and bandwidth characteristics<sup>[3]</sup>. However, they also command higher prices, requiring careful balance between performance requirements and cost constraints. Chinese suppliers increasingly offer piezocomposite options, though specifications and quality control may vary between manufacturers.

### Array Configuration and Spacing

Linear arrays represent the most common and cost-effective configuration for basic flaw detection applications. Element spacing (pitch) significantly affects array performance, with typical values ranging from 0.24mm to several millimeters depending on frequency and application requirements<sup>[4]</sup>. Closer spacing reduces grating lobes but increases manufacturing complexity and cost.

The number of elements directly impacts system performance and cost. While 64-element arrays provide excellent beam control and imaging capabilities<sup>[4]</sup>, functional systems can be built with as few as 8-16 elements

for basic applications. Starting with smaller arrays allows for system development and testing before scaling to larger configurations.

## **Recommended Procurement Strategy**

### **Phased Implementation Approach**

For custom system development, a phased procurement approach minimizes risk and allows for iterative improvement. Begin with small quantities of basic elements from multiple suppliers to evaluate performance and quality. NDT-KITS' \$50 elements provide an excellent starting point for initial prototyping and concept validation<sup>[3]</sup>.

Once basic functionality is demonstrated, consider sourcing larger quantities from Chinese manufacturers to achieve volume pricing. Establish relationships with multiple suppliers to ensure supply chain resilience and competitive pricing. Request samples and detailed specifications before committing to large orders, particularly when working with new suppliers.

### **Quality Assurance and Testing**

Implement incoming inspection procedures for purchased elements, including electrical testing of capacitance, resonant frequency, and impedance characteristics. Basic test equipment can verify element functionality before assembly into arrays. Consider purchasing extra elements to account for potential failures during assembly and testing.

Document supplier performance and element specifications to build a database of reliable sources. Chinese manufacturers often provide competitive pricing but may require more careful quality management compared to established Western suppliers. Building relationships with reputable suppliers like those mentioned in industry rankings can help ensure consistent quality<sup>[11]</sup>.

## **Conclusion**

Building a cost-effective custom ultrasonic phased array system for metal flaw detection is achievable through careful component selection and supplier strategy. Individual elements can be obtained for as little as \$50 each from specialized NDT suppliers, while Chinese manufacturers offer even lower pricing for basic piezoelectric components. Research demonstrates that functional systems can be built for under \$2,000, representing significant savings compared to commercial solutions costing over \$100,000.

Success requires balancing cost considerations with performance requirements, starting with basic configurations and scaling up as experience is gained. Chinese suppliers offer exceptional value but require more careful quality management, while specialized NDT suppliers provide proven components at moderate price premiums. The key to success lies in understanding the trade-offs between cost, performance, and complexity while maintaining focus on the specific requirements of metal flaw detection applications.

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