Motor Predictive Maintenance - Real-Time Data Analysis

Data Collection Format

- **Column 1**: Accelerometer X (g)
- **Column 2**: Accelerometer Y (g)
- **Column 3**: Accelerometer Z (g)
- **Column 4**: Microphone (raw amplitude)
- **Column 5**: Temperature (°C)

Each row represents one sensor reading snapshot.

In [1]:

```
# Import libraries
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from scipy import stats
from scipy.fft import fft, fftfreq

plt.style.use('seaborn-v0_8-darkgrid')
sns.set_palette('husl')
%matplotlib inline

import warnings
warnings.filterwarnings('ignore')

print('✓ Libraries loaded successfully')
```

```
✓ Libraries loaded successfully
```

1. Load Data

In [2]:

```python
# Load data without header
df = pd.read_csv('prediction.csv', header=None, names=['ax_g', 'ay_g', 'az_g', 'mic_raw', 'temp_C'])

# Add reading number as index
df['reading_num'] = range(1, len(df) + 1)

print(f"📊 Data Summary")
print("=" * 60)
print(f"Total readings: {len(df)}")
print(f"Columns: {list(df.columns)}")
print("=" * 60)

# Display first and last few rows
display(df.head(10))
print("\n...\n")
display(df.tail(5))
```

```
📊 Data Summary
============================================================
Total readings: 126
Columns: ['ax_g', 'ay_g', 'az_g', 'mic_raw', 'temp_C', 'reading_num']
============================================================
```

	ax_g	ay_g	az_g	mic_raw	temp_C	reading_num
0	-0.07	0.55	0.84	41036	25.01	1
1	-0.07	0.54	0.85	42004	24.97	2
2	-0.06	0.55	0.85	22548	25.01	3
3	-0.06	0.55	0.85	20030	24.97	4
4	-0.06	0.55	0.85	36974	25.11	5
5	-0.06	0.56	0.84	18142	25.11	6
6	-0.07	0.55	0.83	22624	25.19	7
7	-0.07	0.55	0.86	20032	25.19	8
8	-0.06	0.55	0.85	20508	25.09	9
9	-0.07	0.55	0.85	26800	24.91	10

...

	ax_g	ay_g	az_g	mic_raw	temp_C	reading_num
121	-0.20	0.14	0.94	99146	24.07	122
122	-0.20	0.15	0.98	61048	24.49	123
123	-0.20	0.15	0.98	54222	24.57	124
124	-0.21	0.15	0.98	49726	24.59	125
125	-0.20	0.16	0.98	30960	24.53	126

2. Data Quality & Statistics

In [3]:

```
# Check for missing values
print("Missing Values:")
print(df.isnull().sum())
```

```
print("\n" + "="*60 + "\n")

# Statistical summary
print("Statistical Summary:")
df.describe()
```

```
Missing Values:
ax_g           0
ay_g           0
az_g           0
mic_raw        0
temp_C         0
reading_num    0
dtype: int64

============================================================

Statistical Summary:
```

Out[3]:

	ax_g	ay_g	az_g	mic_raw	temp_C	reading_num
count	126.000000	126.000000	126.000000	1.260000e+02	126.000000	126.000000
mean	-0.072222	0.411111	0.865952	1.225071e+05	26.994286	63.500000
std	0.141652	0.254540	0.287837	5.774671e+05	2.746309	36.517119
min	-1.010000	-0.660000	-1.260000	1.733000e+04	24.070000	1.000000
25%	-0.135000	0.190000	0.850000	2.483750e+04	24.955000	32.250000
50%	-0.040000	0.510000	0.870000	4.494900e+04	25.280000	63.500000
75%	-0.022500	0.540000	0.957500	8.644400e+04	28.730000	94.750000
max	0.430000	1.440000	2.040000	6.496218e+06	33.830000	126.000000

In [4]:

```
# Identify outliers/anomalies
print("🚨 Potential Anomalies (based on extreme values):\n")

# Accelerometer outliers (>1.5g is unusual)
accel_threshold = 1.0
```

```python
accel_outliers = df[(np.abs(df['ax_g']) > accel_threshold) |
                     (np.abs(df['ay_g']) > accel_threshold) |
                     (np.abs(df['az_g']) > accel_threshold)]

if len(accel_outliers) > 0:
    print(f"⚠️  High Vibration Readings ({len(accel_outliers)} occurrences):")
    display(accel_outliers[['reading_num', 'ax_g', 'ay_g', 'az_g', 'temp_C']])

# Microphone outliers (using IQR method)
Q1 = df['mic_raw'].quantile(0.25)
Q3 = df['mic_raw'].quantile(0.75)
IQR = Q3 - Q1
mic_outliers = df[df['mic_raw'] > Q3 + 1.5 * IQR]

if len(mic_outliers) > 0:
    print(f"\n⚠️  Unusual Microphone Readings ({len(mic_outliers)} occurrences):")
    display(mic_outliers[['reading_num', 'mic_raw', 'temp_C', 'ax_g', 'ay_g', 'az_g']].sort_values('mic_

# Temperature extremes
temp_high = df[df['temp_C'] > 32]
if len(temp_high) > 0:
    print(f"\n🌡️  High Temperature Readings (>32°C): {len(temp_high)} occurrences")
    print(f"   Max temp: {df['temp_C'].max():.2f}°C at reading #{df[df['temp_C'] == df['temp_C'].max()][
```

🚨 Potential Anomalies (based on extreme values):

⚠️ High Vibration Readings (9 occurrences):

	reading_num	ax_g	ay_g	az_g	temp_C
11	12	0.24	-0.54	-1.26	25.19
14	15	-0.10	1.44	-0.06	25.33
39	40	-0.17	0.30	1.20	28.85
65	66	0.03	0.64	1.04	28.61
91	92	-0.12	0.24	1.14	25.45
92	93	0.42	-0.33	1.92	25.17
93	94	-0.44	0.40	2.04	24.93
94	95	-1.01	1.21	0.28	24.97
96	97	-0.14	0.01	1.21	24.77

⚠️ Unusual Microphone Readings (12 occurrences):

	reading_num	mic_raw	temp_C	ax_g	ay_g	az_g
96	97	6496218	24.77	-0.14	0.01	1.21
11	12	591314	25.19	0.24	-0.54	-1.26
65	66	358670	28.61	0.03	0.64	1.04
113	114	243662	24.69	-0.21	0.19	0.97
108	109	239538	24.75	-0.21	0.18	0.96
67	68	225578	27.81	-0.02	0.51	0.86
116	117	223820	24.75	-0.21	0.19	0.97
83	84	220140	25.25	-0.03	0.52	0.87
115	116	198176	24.61	-0.20	0.18	0.97
110	111	195878	24.87	-0.20	0.19	0.97
55	56	185882	33.65	-0.04	0.50	0.88
105	106	179312	24.95	-0.22	0.20	0.97

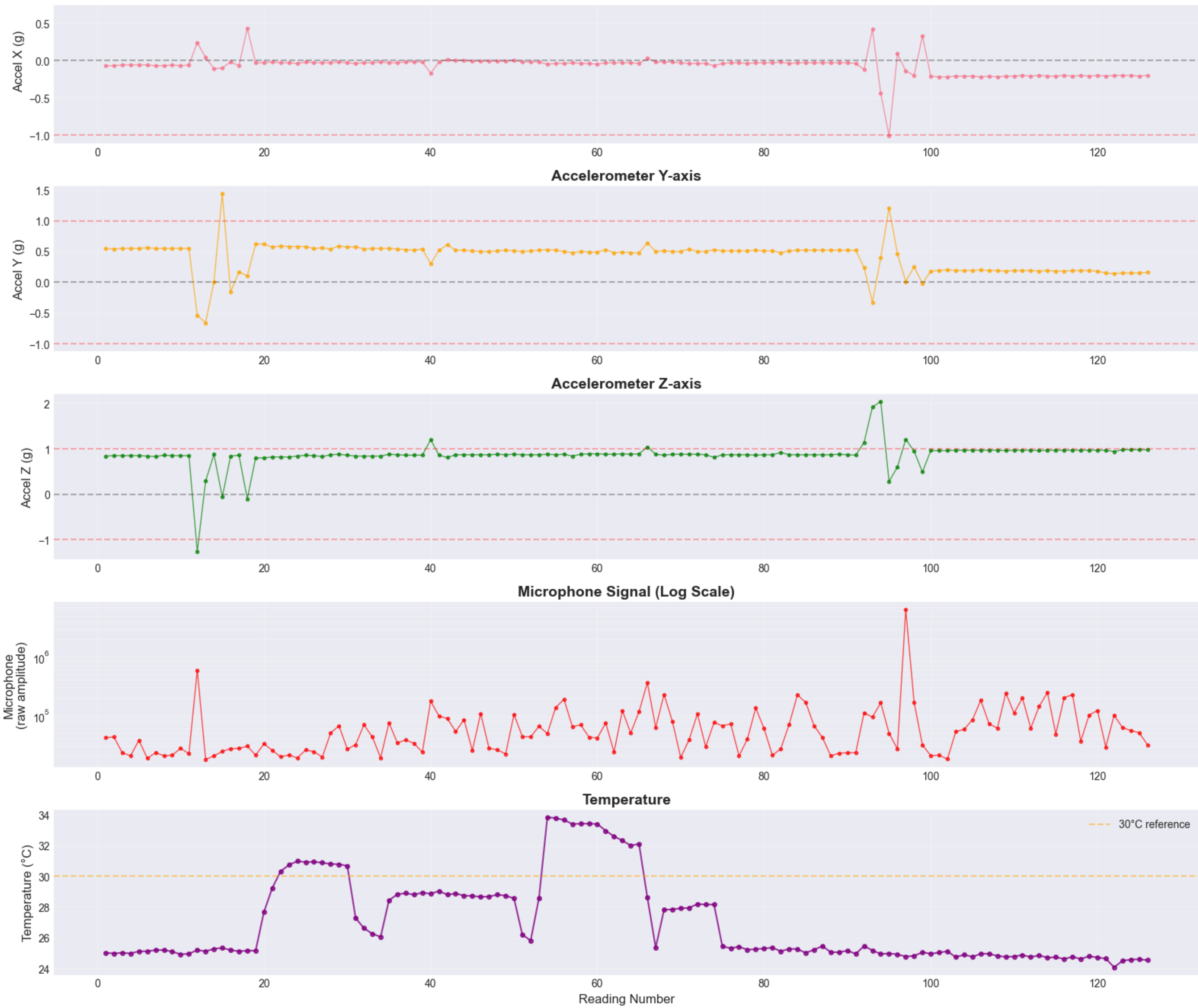
```
🌡️ High Temperature Readings (>32°C): 11 occurrences
   Max temp: 33.83°C at reading #54
```

3. Time Series Visualization

In [5]:

```
# Plot all sensors over time
fig, axes = plt.subplots(5, 1, figsize=(16, 14))

# Accelerometer X
axes[0].plot(df['reading_num'], df['ax_g'], marker='o', markersize=3, linewidth=1, alpha=0.7)
axes[0].axhline(y=0, color='k', linestyle='--', alpha=0.3)
axes[0].axhline(y=1, color='r', linestyle='--', alpha=0.3, label='±1g threshold')
axes[0].axhline(y=-1, color='r', linestyle='--', alpha=0.3)
axes[0].set_ylabel('Accel X (g)', fontsize=12)
axes[0].set_title('Accelerometer X-axis - Full History', fontsize=14, fontweight='bold')
axes[0].legend()
```

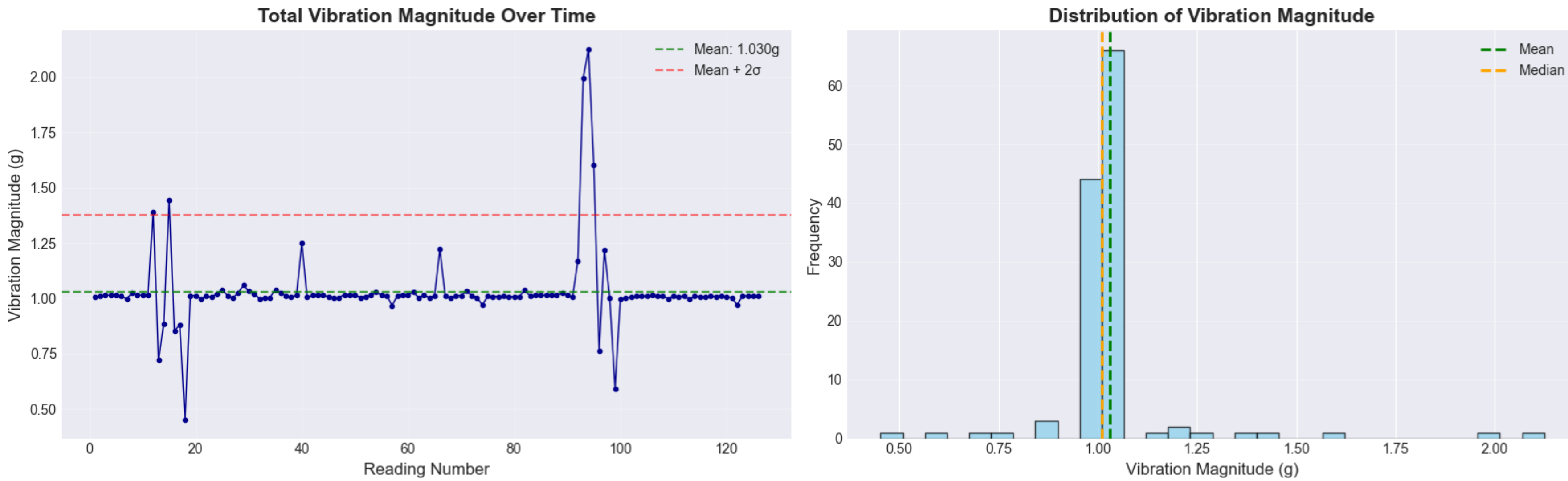
```
axes[0].grid(True, alpha=0.3)

# Accelerometer Y
axes[1].plot(df['reading_num'], df['ay_g'], marker='o', markersize=3, linewidth=1, alpha=0.7, color='oran
axes[1].axhline(y=0, color='k', linestyle='--', alpha=0.3)
axes[1].axhline(y=1, color='r', linestyle='--', alpha=0.3)
axes[1].axhline(y=-1, color='r', linestyle='--', alpha=0.3)
axes[1].set_ylabel('Accel Y (g)', fontsize=12)
axes[1].set_title('Accelerometer Y-axis', fontsize=14, fontweight='bold')
axes[1].grid(True, alpha=0.3)

# Accelerometer Z
axes[2].plot(df['reading_num'], df['az_g'], marker='o', markersize=3, linewidth=1, alpha=0.7, color='gree
axes[2].axhline(y=0, color='k', linestyle='--', alpha=0.3)
axes[2].axhline(y=1, color='r', linestyle='--', alpha=0.3)
axes[2].axhline(y=-1, color='r', linestyle='--', alpha=0.3)
axes[2].set_ylabel('Accel Z (g)', fontsize=12)
axes[2].set_title('Accelerometer Z-axis', fontsize=14, fontweight='bold')
axes[2].grid(True, alpha=0.3)

# Microphone (log scale due to huge range)
axes[3].plot(df['reading_num'], df['mic_raw'], marker='o', markersize=3, linewidth=1, alpha=0.7, color='
axes[3].set_ylabel('Microphone\n(raw amplitude)', fontsize=12)
axes[3].set_yscale('log')  # Log scale to see patterns
axes[3].set_title('Microphone Signal (Log Scale)', fontsize=14, fontweight='bold')
axes[3].grid(True, alpha=0.3, which='both')

# Temperature
axes[4].plot(df['reading_num'], df['temp_C'], marker='o', markersize=4, linewidth=1.5, alpha=0.8, color=
axes[4].axhline(y=30, color='orange', linestyle='--', alpha=0.5, label='30°C reference')
axes[4].set_ylabel('Temperature (°C)', fontsize=12)
axes[4].set_xlabel('Reading Number', fontsize=12)
axes[4].set_title('Temperature', fontsize=14, fontweight='bold')
axes[4].legend()
axes[4].grid(True, alpha=0.3)

plt.tight_layout()
plt.show()
```



Accel X (g)
Accelerometer Y-axis
Accel Y (g)
Accelerometer Z-axis
Accel Z (g)
Microphone Signal (Log Scale)
Microphone
(raw amplitude)
Temperature
Temperature (°C)
30°C reference
Reading Number

4. Vibration Magnitude Analysis

In [6]:
```
# Calculate overall vibration magnitude
df['vibration_magnitude'] = np.sqrt(df['ax_g']**2 + df['ay_g']**2 + df['az_g']**2)

fig, axes = plt.subplots(1, 2, figsize=(16, 5))

# Vibration magnitude over time
axes[0].plot(df['reading_num'], df['vibration_magnitude'], marker='o', markersize=3, linewidth=1, color=
axes[0].axhline(y=df['vibration_magnitude'].mean(), color='green', linestyle='--',
                alpha=0.7, label=f"Mean: {df['vibration_magnitude'].mean():.3f}g")
axes[0].axhline(y=df['vibration_magnitude'].mean() + 2*df['vibration_magnitude'].std(),
                color='red', linestyle='--', alpha=0.5, label='Mean + 2σ')
axes[0].set_xlabel('Reading Number', fontsize=12)
axes[0].set_ylabel('Vibration Magnitude (g)', fontsize=12)
axes[0].set_title('Total Vibration Magnitude Over Time', fontsize=14, fontweight='bold')
axes[0].legend()
axes[0].grid(True, alpha=0.3)

# Distribution of vibration magnitude
axes[1].hist(df['vibration_magnitude'], bins=30, edgecolor='black', alpha=0.7, color='skyblue')
axes[1].axvline(x=df['vibration_magnitude'].mean(), color='green', linestyle='--', linewidth=2, label='Me
axes[1].axvline(x=df['vibration_magnitude'].median(), color='orange', linestyle='--', linewidth=2, label=
axes[1].set_xlabel('Vibration Magnitude (g)', fontsize=12)
axes[1].set_ylabel('Frequency', fontsize=12)
axes[1].set_title('Distribution of Vibration Magnitude', fontsize=14, fontweight='bold')
axes[1].legend()
axes[1].grid(True, alpha=0.3, axis='y')

plt.tight_layout()
plt.show()

print(f"Vibration Statistics:")
print(f"  Mean: {df['vibration_magnitude'].mean():.4f}g")
print(f"  Std:  {df['vibration_magnitude'].std():.4f}g")
print(f"  Max:  {df['vibration_magnitude'].max():.4f}g (reading #{df['vibration_magnitude'].idxmax() + 1}
```




```
Vibration Statistics:
  Mean: 1.0300g
  Std:  0.1724g
  Max:  2.1249g (reading #94)
```

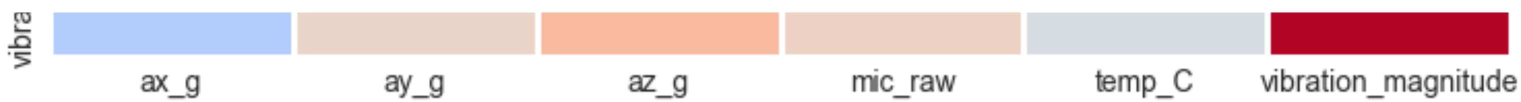
5. Correlation Analysis

In [7]:

```python
# Create correlation matrix
corr_cols = ['ax_g', 'ay_g', 'az_g', 'mic_raw', 'temp_C', 'vibration_magnitude']
corr_matrix = df[corr_cols].corr()

plt.figure(figsize=(10, 8))
sns.heatmap(corr_matrix, annot=True, cmap='coolwarm', center=0,
            square=True, linewidths=2, cbar_kws={"shrink": 0.8}, fmt='.2f',
            vmin=-1, vmax=1)
plt.title('Sensor Correlation Matrix', fontsize=16, fontweight='bold', pad=20)
plt.tight_layout()
plt.show()

print("\n🔍 Key Correlations:")
print(f"  Temperature vs Vibration Magnitude: {df['temp_C'].corr(df['vibration_magnitude']):.3f}")
print(f"  Temperature vs Microphone: {df['temp_C'].corr(df['mic_raw']):.3f}")
```

Sensor Correlation Matrix


ax_g
ay_g
az_g
mic_raw
temp_C
1.00 -0.13 -0.23 -0.04 0.25 -0.29
-0.13 1.00 -0.00 -0.18 0.35 0.11
-0.23 -0.00 1.00 0.08 0.00 0.31
-0.04 -0.18 0.08 1.00 -0.08 0.13
0.25 0.35 0.00 -0.08 1.00 -0.04
-0.29 0.11 0.31 0.13 -0.04 1.00
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00

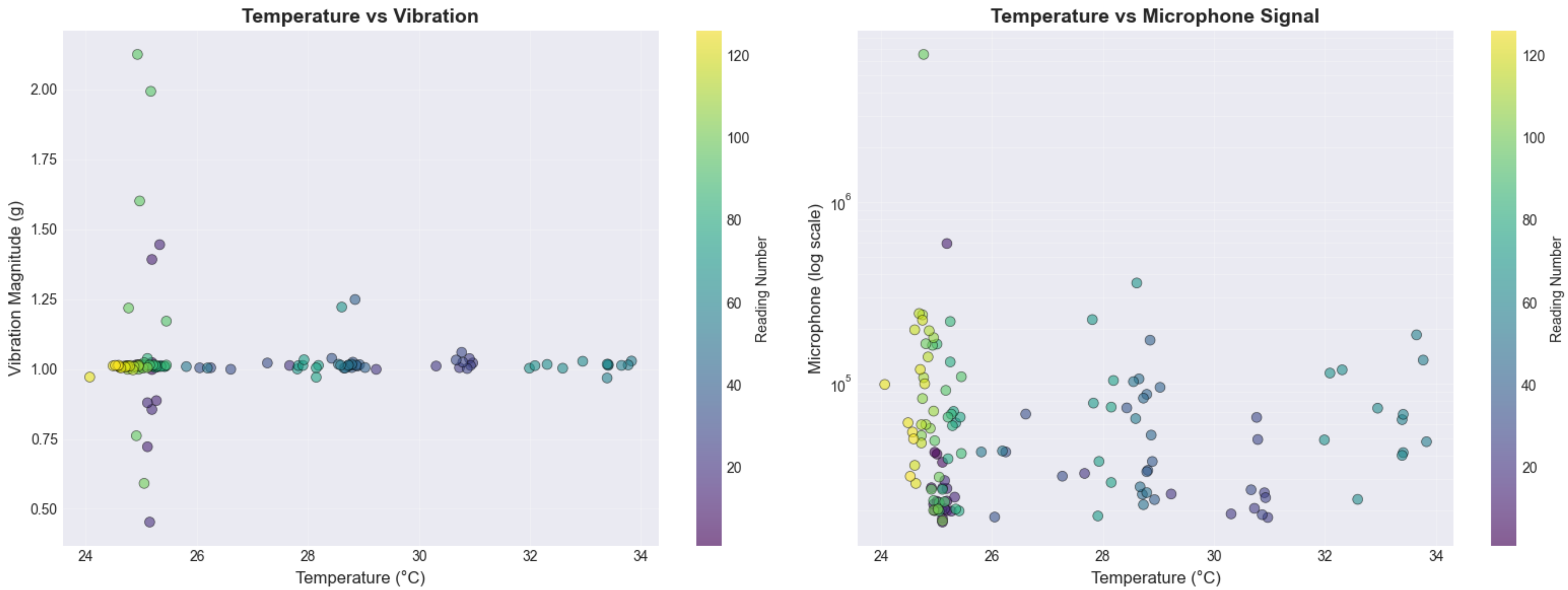



```
🔍 Key Correlations:
 Temperature vs Vibration Magnitude: -0.039
 Temperature vs Microphone: -0.079
```

6. Scatter Plots - Relationship Analysis

In [8]:

```python
fig, axes = plt.subplots(1, 2, figsize=(16, 6))

# Temperature vs Vibration
scatter1 = axes[0].scatter(df['temp_C'], df['vibration_magnitude'],
                           c=df['reading_num'], cmap='viridis',
                           s=50, alpha=0.6, edgecolors='black', linewidth=0.5)
axes[0].set_xlabel('Temperature (°C)', fontsize=12)
axes[0].set_ylabel('Vibration Magnitude (g)', fontsize=12)
axes[0].set_title('Temperature vs Vibration', fontsize=14, fontweight='bold')
axes[0].grid(True, alpha=0.3)
plt.colorbar(scatter1, ax=axes[0], label='Reading Number')

# Temperature vs Microphone (log scale)
scatter2 = axes[1].scatter(df['temp_C'], df['mic_raw'],
                           c=df['reading_num'], cmap='viridis',
                           s=50, alpha=0.6, edgecolors='black', linewidth=0.5)
axes[1].set_xlabel('Temperature (°C)', fontsize=12)
axes[1].set_ylabel('Microphone (log scale)', fontsize=12)
axes[1].set_yscale('log')
axes[1].set_title('Temperature vs Microphone Signal', fontsize=14, fontweight='bold')
axes[1].grid(True, alpha=0.3, which='both')
plt.colorbar(scatter2, ax=axes[1], label='Reading Number')

plt.tight_layout()
plt.show()
```

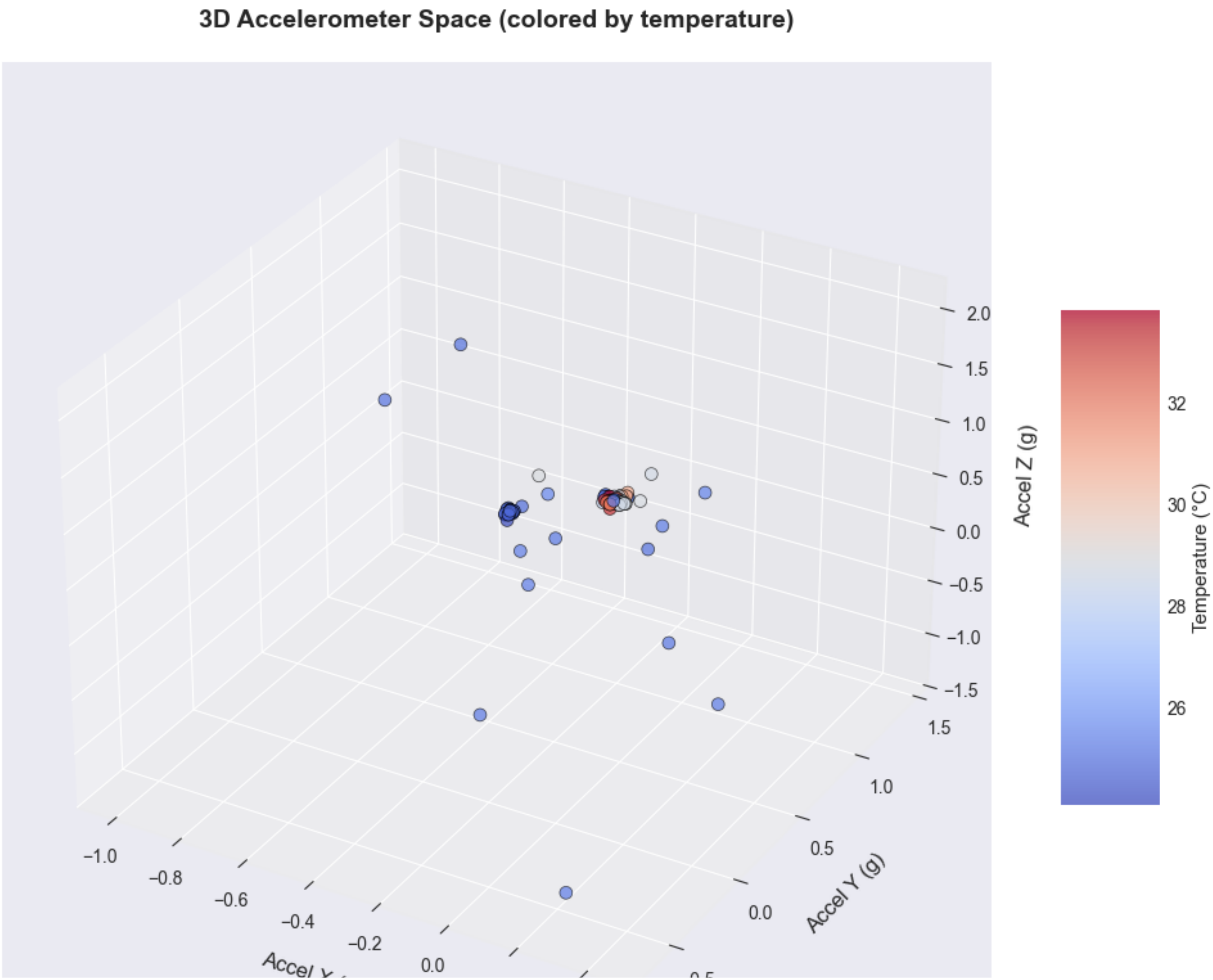


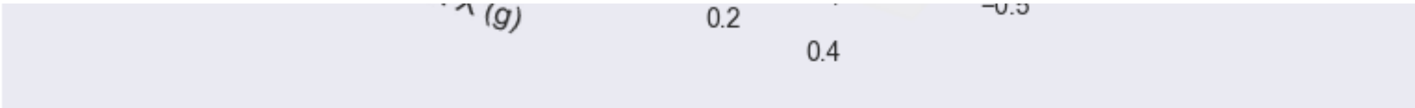
7. 3D Accelerometer Visualization

In [9]:

```
from mpl_toolkits.mplot3d import Axes3D

fig = plt.figure(figsize=(14, 10))
ax = fig.add_subplot(111, projection='3d')

scatter = ax.scatter(df['ax_g'], df['ay_g'], df['az_g'],
                     c=df['temp_C'], cmap='coolwarm',
                     s=50, alpha=0.7, edgecolors='black', linewidth=0.5)

ax.set_xlabel('Accel X (g)', fontsize=12, labelpad=10)
ax.set_ylabel('Accel Y (g)', fontsize=12, labelpad=10)
ax.set_zlabel('Accel Z (g)', fontsize=12, labelpad=10)
ax.set_title('3D Accelerometer Space (colored by temperature)', fontsize=14, fontweight='bold', pad=20)

cbar = plt.colorbar(scatter, ax=ax, shrink=0.5, aspect=5)
cbar.set_label('Temperature (°C)', fontsize=11)
```

```
plt.show()
```

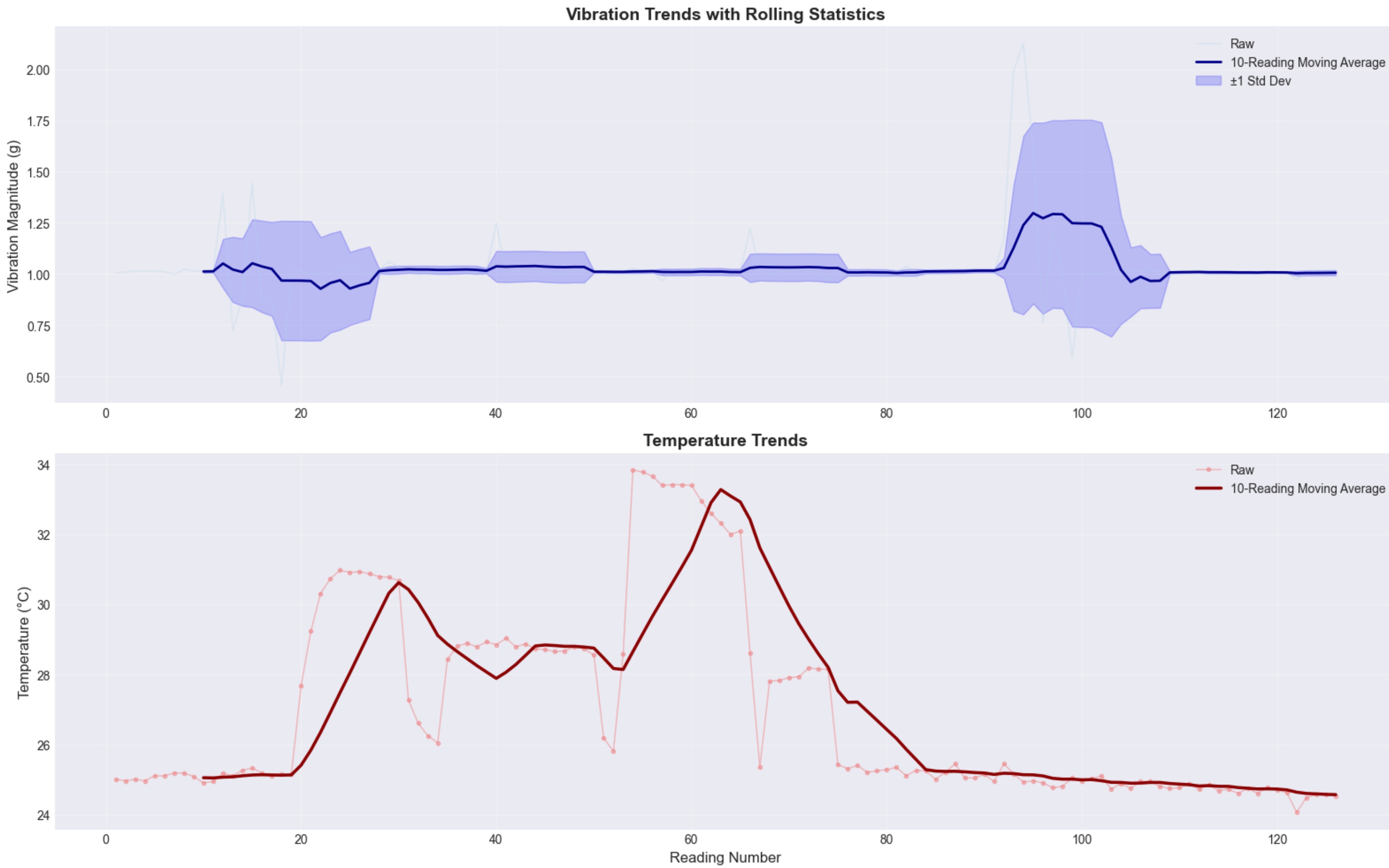

3D Accelerometer Space (colored by temperature)
Accel Z (g)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Accel Y (g)
1.5
1.0
0.5
0.0
Accel X
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
Temperature (°C)
32
30
28
26



8. Rolling Statistics (Trends)

In [10]:
```
# Calculate rolling statistics
window = 10  # 10-reading window

df['vibration_rolling_mean'] = df['vibration_magnitude'].rolling(window=window).mean()
df['vibration_rolling_std'] = df['vibration_magnitude'].rolling(window=window).std()
df['temp_rolling_mean'] = df['temp_C'].rolling(window=window).mean()

fig, axes = plt.subplots(2, 1, figsize=(16, 10))

# Vibration trends
axes[0].plot(df['reading_num'], df['vibration_magnitude'],
             alpha=0.3, linewidth=1, label='Raw', color='lightblue')
axes[0].plot(df['reading_num'], df['vibration_rolling_mean'],
             linewidth=2, label=f'{window}-Reading Moving Average', color='darkblue')
axes[0].fill_between(df['reading_num'],
                     df['vibration_rolling_mean'] - df['vibration_rolling_std'],
                     df['vibration_rolling_mean'] + df['vibration_rolling_std'],
                     alpha=0.2, color='blue', label='±1 Std Dev')
axes[0].set_ylabel('Vibration Magnitude (g)', fontsize=12)
axes[0].set_title('Vibration Trends with Rolling Statistics', fontsize=14, fontweight='bold')
axes[0].legend()
axes[0].grid(True, alpha=0.3)

# Temperature trends
axes[1].plot(df['reading_num'], df['temp_C'],
             alpha=0.5, linewidth=1, marker='o', markersize=3, label='Raw', color='lightcoral')
axes[1].plot(df['reading_num'], df['temp_rolling_mean'],
             linewidth=2.5, label=f'{window}-Reading Moving Average', color='darkred')
axes[1].set_xlabel('Reading Number', fontsize=12)
axes[1].set_ylabel('Temperature (°C)', fontsize=12)
axes[1].set_title('Temperature Trends', fontsize=14, fontweight='bold')
axes[1].legend()
```

```
axes[1].grid(True, alpha=0.3)

plt.tight_layout()
plt.show()
```



9. Summary Report

In [11]:

```
print("="*70)
print(" MOTOR HEALTH SUMMARY REPORT")
print("="*70)

print(f"\n📊 Dataset Overview:")
print(f"   Total Readings: {len(df)}")
print(f"   Data Collection: Ongoing (real-time)")

print(f"\n🔧 Vibration Analysis:")
print(f"   Mean Magnitude: {df['vibration_magnitude'].mean():.4f}g")
print(f"   Std Deviation: {df['vibration_magnitude'].std():.4f}g")
print(f"   Max Observed: {df['vibration_magnitude'].max():.4f}g")
high_vib = len(df[df['vibration_magnitude'] > 1.5])
print(f"   High Vibration Events (>1.5g): {high_vib} ({high_vib/len(df)*100:.1f}%)")

print(f"\n🌡️  Temperature Analysis:")
print(f"   Current: {df['temp_C'].iloc[-1]:.2f}°C")
print(f"   Mean: {df['temp_C'].mean():.2f}°C")
print(f"   Range: {df['temp_C'].min():.2f}°C - {df['temp_C'].max():.2f}°C")
print(f"   Trend: {'↑ Rising' if df['temp_C'].iloc[-10:].mean() > df['temp_C'].iloc[:10].mean() else '↓ F

print(f"\n🎤 Microphone Analysis:")
print(f"   Median: {df['mic_raw'].median():.0f}")
print(f"   Max Peak: {df['mic_raw'].max():.0f}")
print(f"   Outliers Detected: {len(mic_outliers)}")

print(f"\n⚠️  Anomaly Detection:")
if len(accel_outliers) > 0:
    print(f"   🔴 {len(accel_outliers)} High Vibration Anomalies Detected")
else:
    print(f"   ✅ No High Vibration Anomalies")

if df['temp_C'].max() > 32:
    print(f"   🟡 Temperature exceeded 32°C ({df['temp_C'].max():.1f}°C max)")
else:
    print(f"   ✅ Temperature within normal range")

print(f"\n💡 Recommendations:")
if high_vib > 5:
    print("   - Monitor motor for unusual vibrations")
```

```
    print("   - Check mounting and alignment")
if df['temp_C'].max() > 32:
    print("   - Monitor temperature trends closely")
    print("   - Ensure adequate cooling")
if len(df) < 100:
    print("   - Continue collecting baseline data")
    print("   - Need more readings to establish normal patterns")
else:
    print("   - Sufficient data for initial baseline analysis")
    print("   - Ready for anomaly detection model training")

print("\n" + "="*70)
```

```
======================================================================
 MOTOR HEALTH SUMMARY REPORT
======================================================================

📊 Dataset Overview:
   Total Readings: 126
   Data Collection: Ongoing (real-time)

🔧 Vibration Analysis:
   Mean Magnitude: 1.0300g
   Std Deviation: 0.1724g
   Max Observed: 2.1249g
   High Vibration Events (>1.5g): 3 (2.4%)

🌡️  Temperature Analysis:
   Current: 24.53°C
   Mean: 26.99°C
   Range: 24.07°C - 33.83°C
   Trend: ↓ Falling

🎤 Microphone Analysis:
   Median: 44949
   Max Peak: 6496218
   Outliers Detected: 12

⚠️  Anomaly Detection:
   🔴 9 High Vibration Anomalies Detected
   🟡 Temperature exceeded 32°C (33.8°C max)

💡 Recommendations:
   - Monitor temperature trends closely
   - Ensure adequate cooling
   - Sufficient data for initial baseline analysis
   - Ready for anomaly detection model training

======================================================================
```

10. Export Processed Data

In [12]:
```python
# Save processed data with calculated features
df.to_csv('motor_data_processed.csv', index=False)
print('✓ Processed data saved to: motor_data_processed.csv')

# Save summary statistics
summary = df[['ax_g', 'ay_g', 'az_g', 'mic_raw', 'temp_C', 'vibration_magnitude']].describe()
summary.to_csv('motor_data_summary.csv')
print('✓ Summary statistics saved to: motor_data_summary.csv')
```

```
✓ Processed data saved to: motor_data_processed.csv
✓ Summary statistics saved to: motor_data_summary.csv
```

Next Steps:

1. **Continue Data Collection**: Keep adding readings to build a comprehensive baseline
2. **Label Data**: Mark readings during known motor states (normal, high load, etc.)
3. **Feature Engineering**: Create more sophisticated features from raw signals
4. **Anomaly Detection**: Once baseline established, train unsupervised models
5. **Real-time Monitoring**: Set up alerts for unusual patterns