KLASYFIKATOR SYGNAŁU NA SYSTEMIE WBUDOWANYM

Wstęp do projektu z WDSSN

ZAŁOŻENIA PROJEKTU

- Na czym będziemy pracować
- Co będzie potrafiła nasza sieć
- Zestaw danych dla sieci

PROPONOWANY HARDWARE

- MIKROKONTROLER STM32 (PROSTOTA IMPLEMENTACJI KOSZTEM WYDAJNOŚCI)
- WBUDOWANY ADC DO ZAPEWNIENIA DANYCH WEJŚCIOWYCH
- PROSTA KOMUNIKACJA Z UŻYTKOWNIKIEM (UART?)

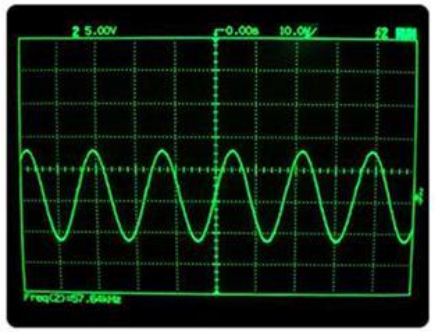
DANE TRENINGOWE

Zestaw danych treningowych zostanie wygenerowany wraz z odpowiednim etykietowaniem z pomocą skryptu w pythonie. Użycie sztucznego zbioru danych jest spowodowane prostotą jego uzyskania (w przeciwieństwie do zbierania danych za pomocą rzeczywistych urządzeń).

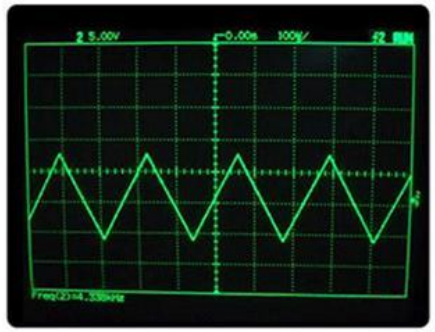
RODZAJE SYGNAŁÓW

AI powinno klasyfikować i rozpoznawać rodzaje sygnału generowanego przez urządzenie zewnętrzne.

Bardziej zaawansowaną funkcją jaką chcielibyśmy zaimplementować jest rozpoznawanie częstotliwości (jeżeli pozwoli czas).

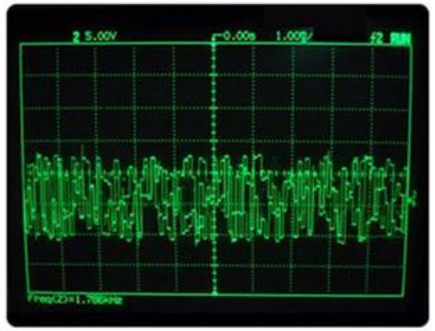


Sine wave

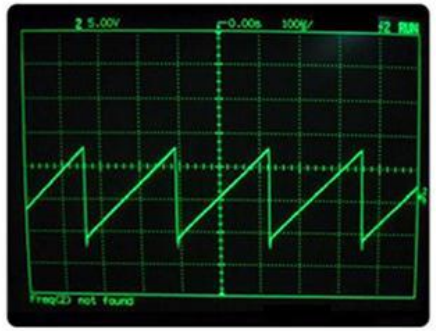


Triangle wave

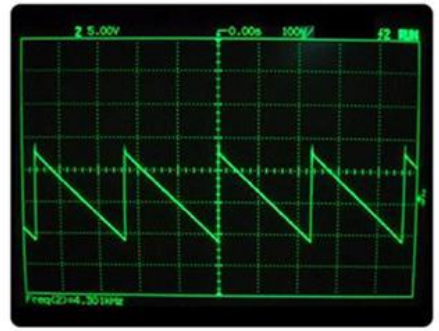
ECG wave



Noise wave



Sawtooth



Reverse sawtooth

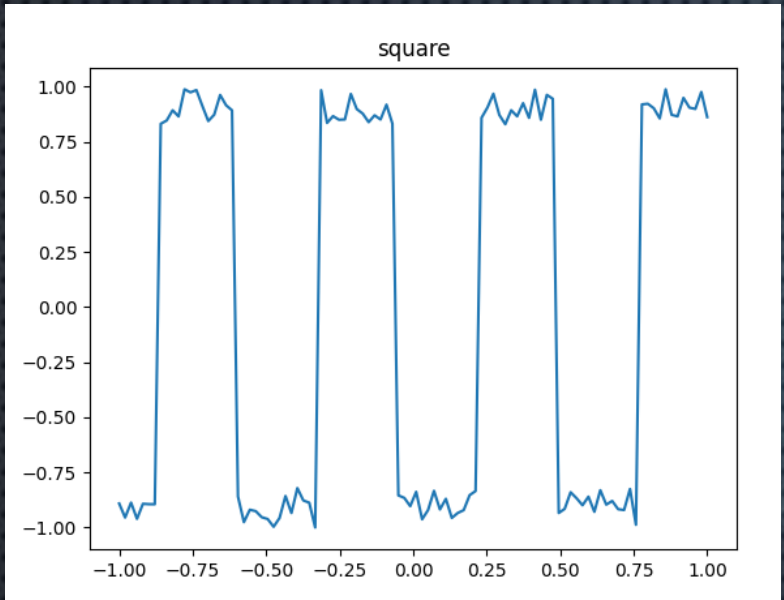
DANE TRENINGOWE

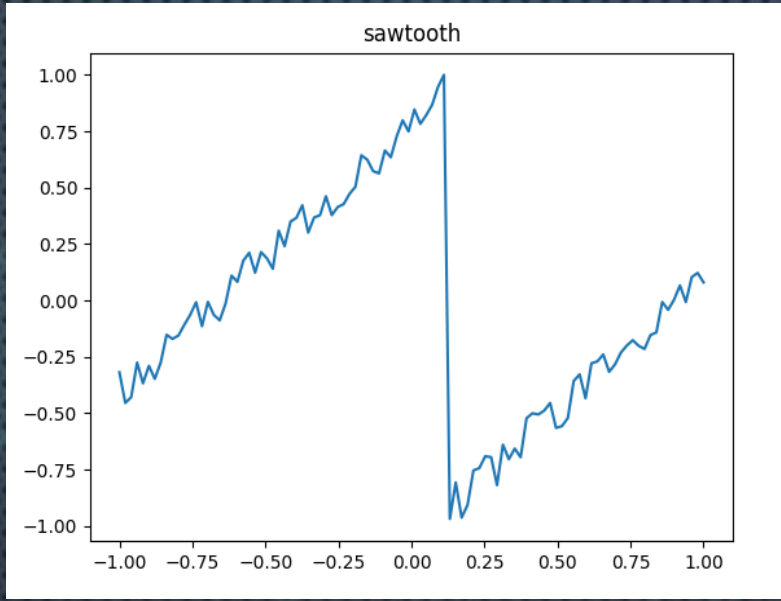
SKRYPT DO GENEROWANIA DANYCH:

- HTTPS://GITHUB.COM/M-CHWAST/WDSSN-PROJECT/TREE/DATA-GEN/DATA-GEN

W POROSTY SPOSÓB MOŻEMY GENEROWAĆ DOWOLNĄ ILOŚĆ DANYCH

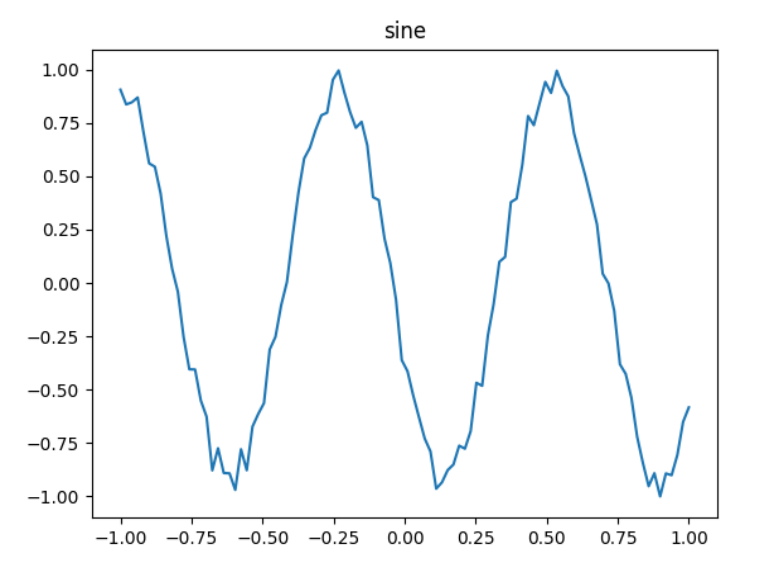
```python
def generate_random(
        self,
        samples : int,
        sample_time_us : float = 1000,
        amplitude : float = 1,
        noise_percent : float = 10
    ) -> tuple[np.ndarray, str]:

    sample_time = sample_time_us / 1_000_000

    observation_time = samples * sample_time
    fmin, fmax = self.__get_freq_limits(observation_time)
    freq = self.__get_freq(fmin, fmax)
    phase_t = (self.__get_phase() / 2 * math.pi) * (1 / freq)

    signal = np.zeros(samples)
    for i in range(0, samples):
        t = i * sample_time + phase_t
        arg = 2 * math.pi * freq * t

        sample = self.get_sample(arg)
        noise = self.__get_noise(amplitude=1, noise_percent=noise_percent)
        sample += noise

        signal[i] = sample
    signal = self.normalize(signal, amplitude)
    return signal, self.get_label()
```

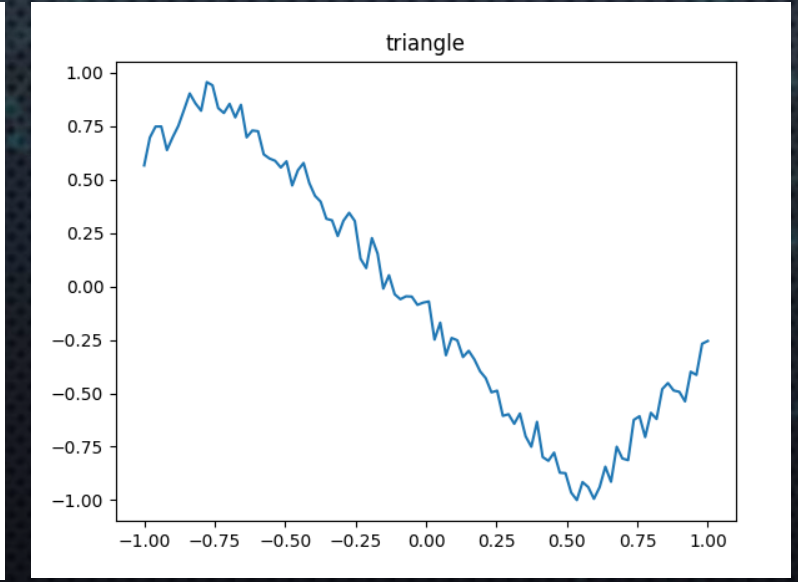





```
class Sine(SignalBase):
    def get_sample(self, arg : float) -> float:
        return math.sin(arg)
```

```
class Square(SignalBase):
    def get_sample(self, arg: float) -> float:
        return square(t=arg, duty=0.5)
```



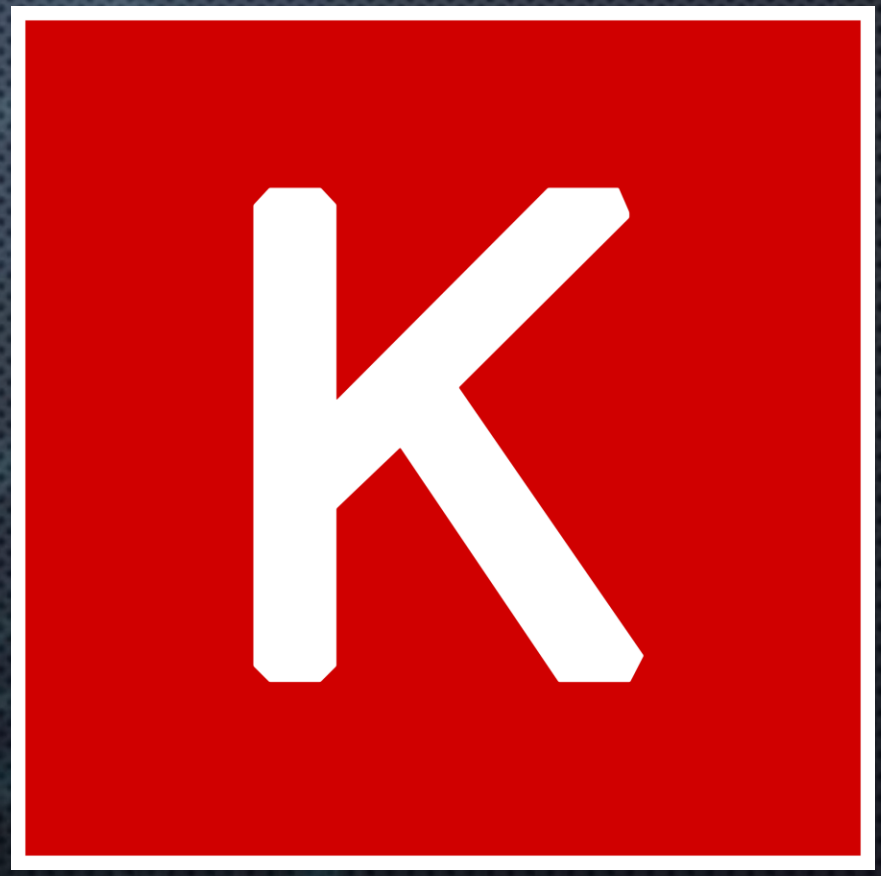



```
class Sawtooth(SignalBase):
    def get_sample(self, arg : float) -> float:
        return sawtooth(t=arg)
```

```
class Triangle(SignalBase):
    def get_sample(self, arg: float) -> float:
        return sawtooth(t=arg, width=0.5)
```

API KERAS

- Prostota
- Styczność
- Społeczność i wsparcie

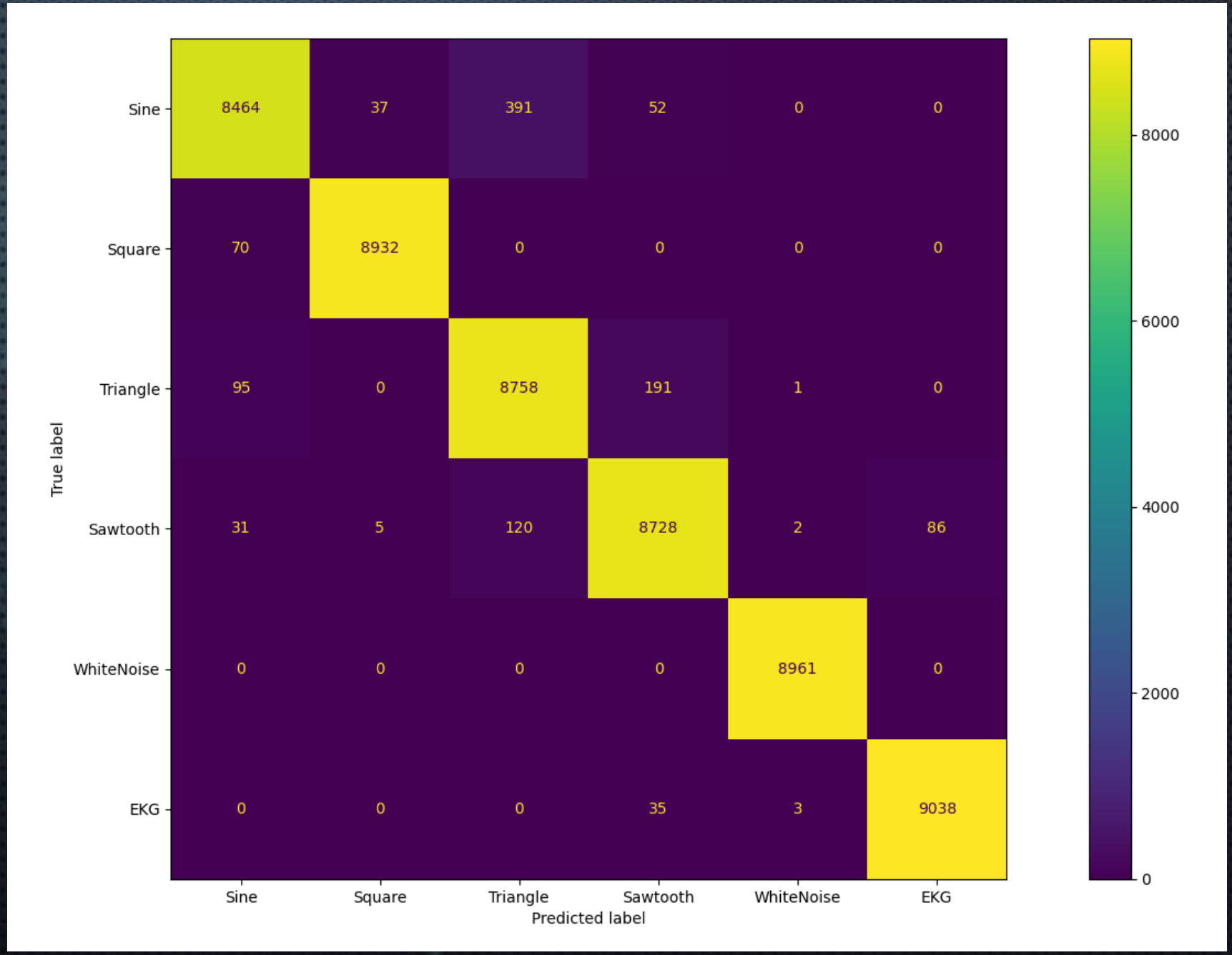


ROZSZERZANIE DANYCH

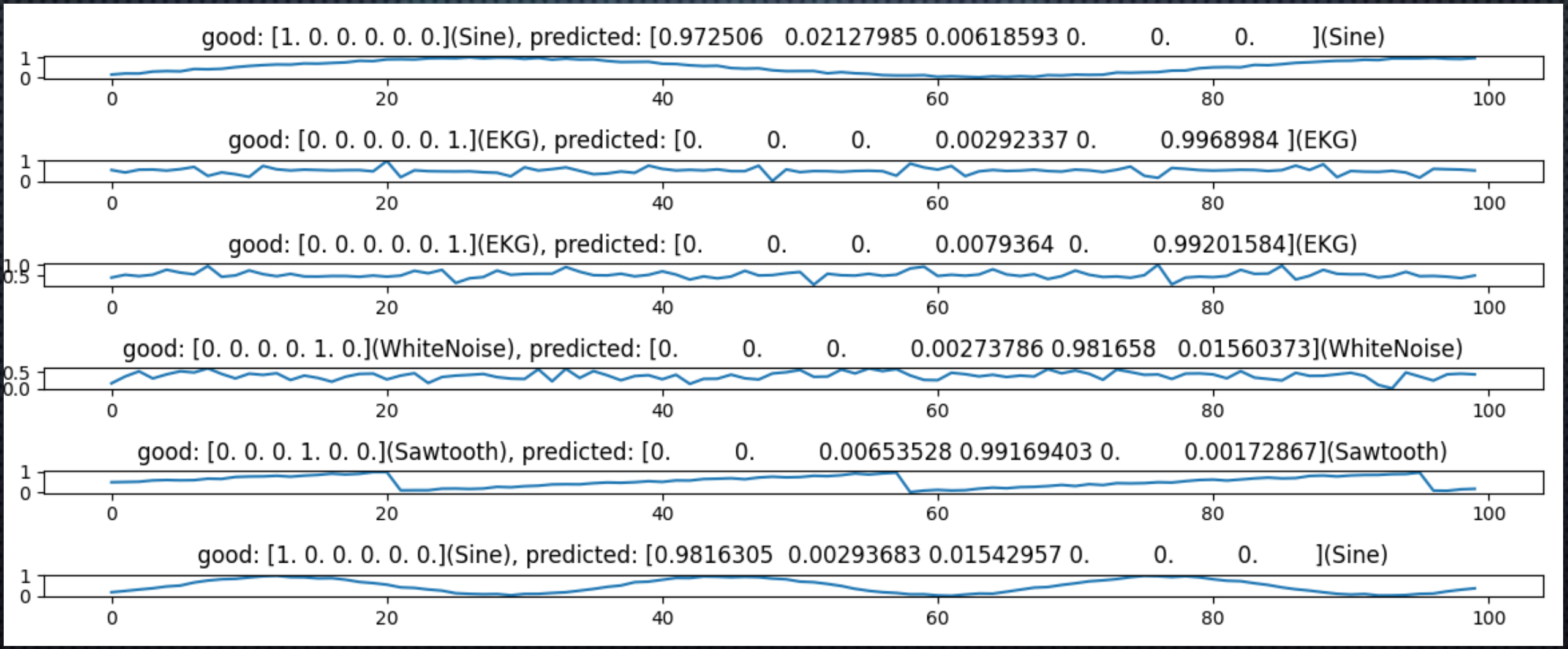
JAKIKOLWIEK WZÓR

```
class EKG(SignalBase):
    N = 10
    RATIO = 0.235
    def get_sample(self, arg: float) -> float:
        return self.RATIO * sum(
            math.sin(0.2 * i * math.pi * arg - i / 2 * math.pi)
          * math.cos(1.1 * i * math.pi * arg) for i in range(self.N)
        )


class WhiteNoise(SignalBase):
    def get_sample(self, arg: float) -> float:
        return np.random.normal(-1, 1, 1)



class "Twój sygnał"(SignalBase):

    def get_sample(self, arg: float) -> float:
        return "Wartość w punkcie 'arg'"
```

CONFUSION MATRIX



JEDNORODNOŚĆ WYNIKÓW



Optymalizacja - założenia

- Wykorzystanie biblioteki tflite, ze względu na możliwość wykonywania operacji na modelu wygenerowanym prez Keras
- Wykonanie kwantyzacji w celu zmniejszenia rozmiaru modelu oraz latencji
- Opcjonalnie wykonanie pruningu (w celu polepszenia zdolności modelu do kompresji) - krok ten może nie być konieczny ze względu na prostotę modelu

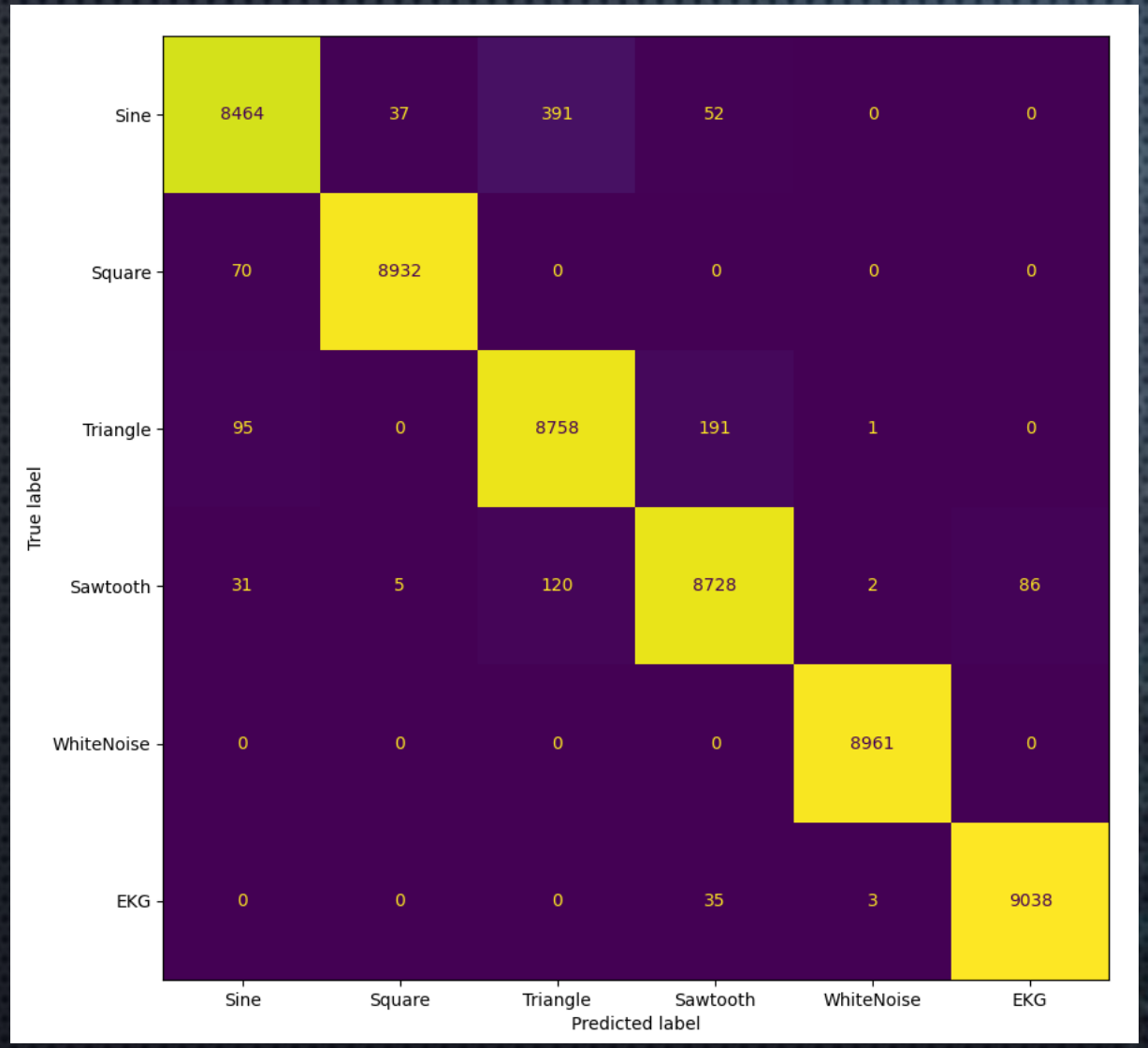
OPTYMALIZACJA - EFEKTY

Zmniejszenie rozmiaru modelu (zapisanego w pliku .tflite):

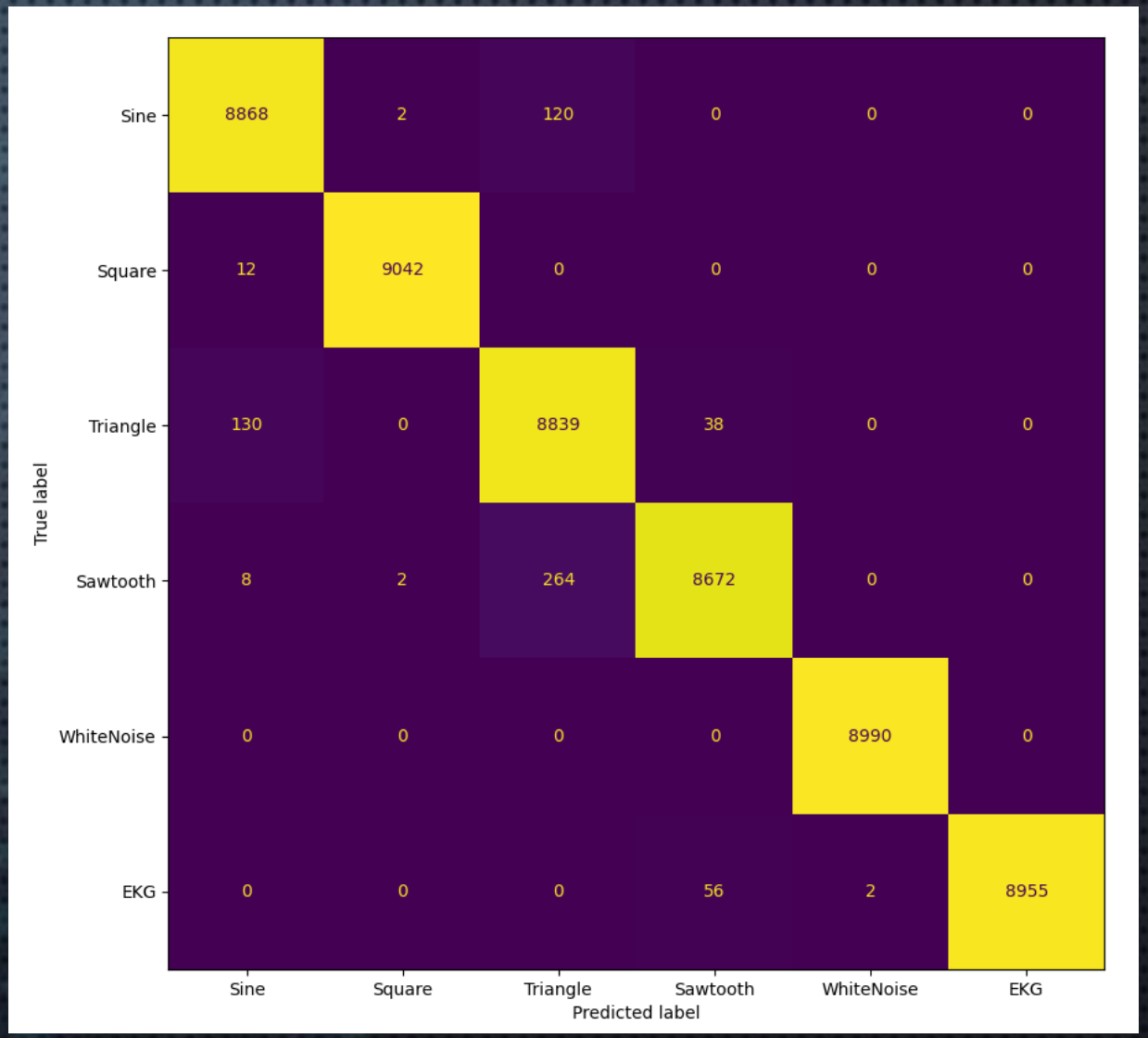
- przed kwantyzacją: 19.8 kB
- po kwantyzacji: 8.1 kB

Zmiana accuracy:

- przed kwantyzacją: 98.58%
- po kwantyzacji: 98.82% - nieznaczny przyrost



Przed kwantyzacją



Po kwantyzacji

Implementacja fizyczna systemu

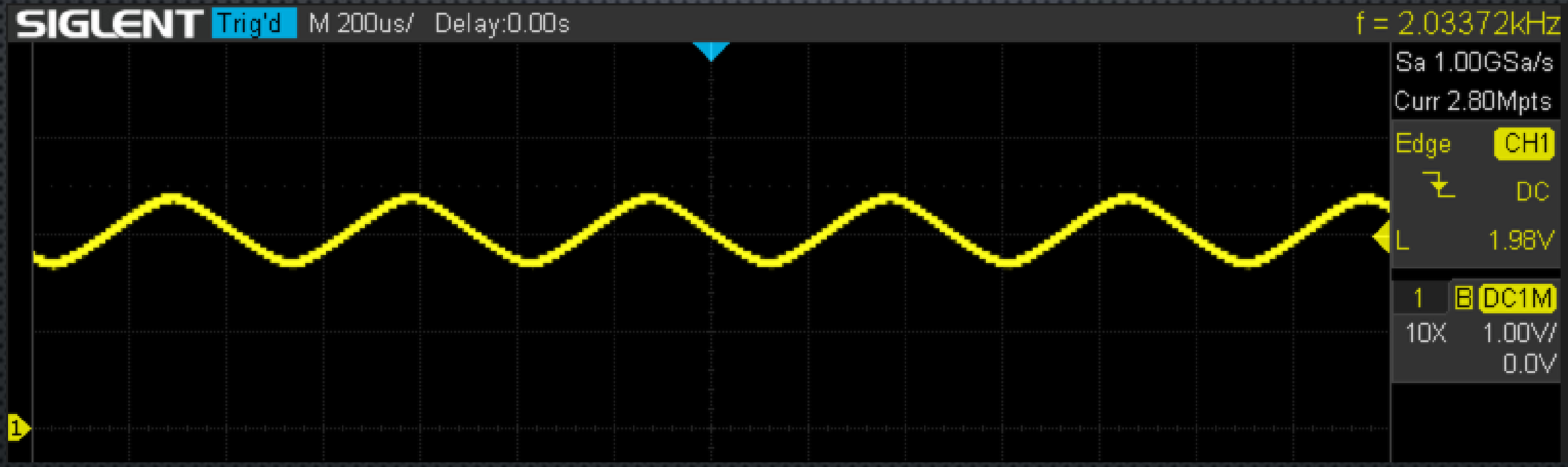
Końcowa implementacja wykorzystuje bibliotekę tflite-micro (C++).

Rozmiar użytego modelu jest zaniedbywalny w porównaniu do rozmiaru biblioteki (8kB model, ok. 300 kB biblioteka, optymalizacja –o0). Dla bardziej skomplikowanych modeli widać jednak duże zalety kwantyzacji.

Układ cyklicznie pobiera 100 sampli (100 ksps, co przekłada się na bazową częstotliwość 1 kHz), przetwarza je w celu zapewnienia wejścia zgodnego z treningowym (rozpiętość sygnału 0-1) a następnie dokonuje predykcji.

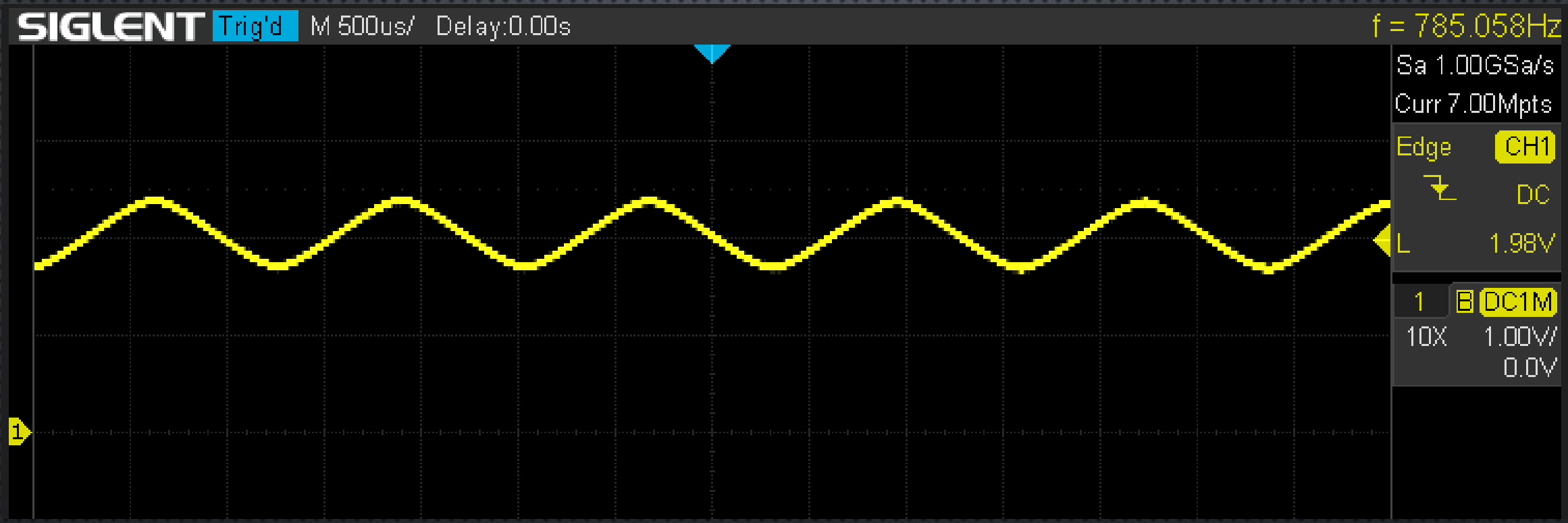
Testy zostały wykonane dla 3 typów sygnału: sinus, trójkąt I prostokąt.

SIN 2 KHZ



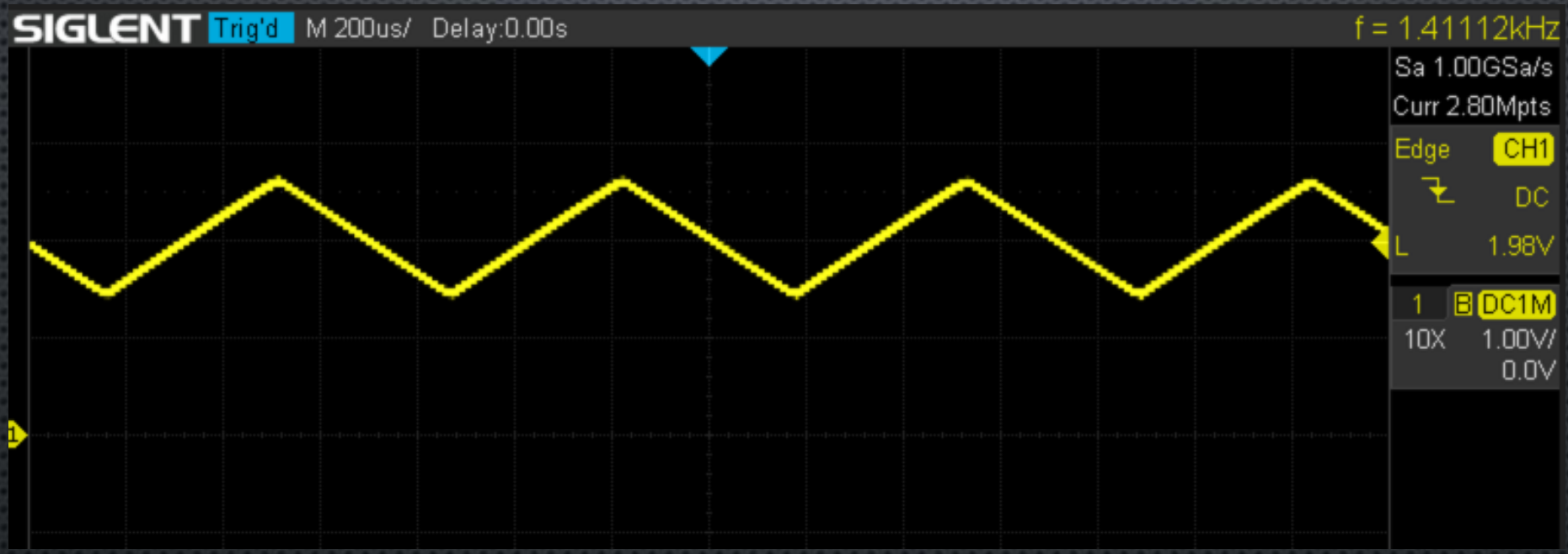

```
Result: Sine                    Percents: Sine=88.6%, Square=7.0%, Triangle=4.2%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Sine                    Percents: Sine=87.8%, Square=0.7%, Triangle=11.3%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Sine                    Percents: Sine=89.0%, Square=1.1%, Triangle=9.7%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Sine                    Percents: Sine=91.4%, Square=1.5%, Triangle=7.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Sine                    Percents: Sine=90.2%, Square=1.5%, Triangle=8.2%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
```

SIN 800 HZ



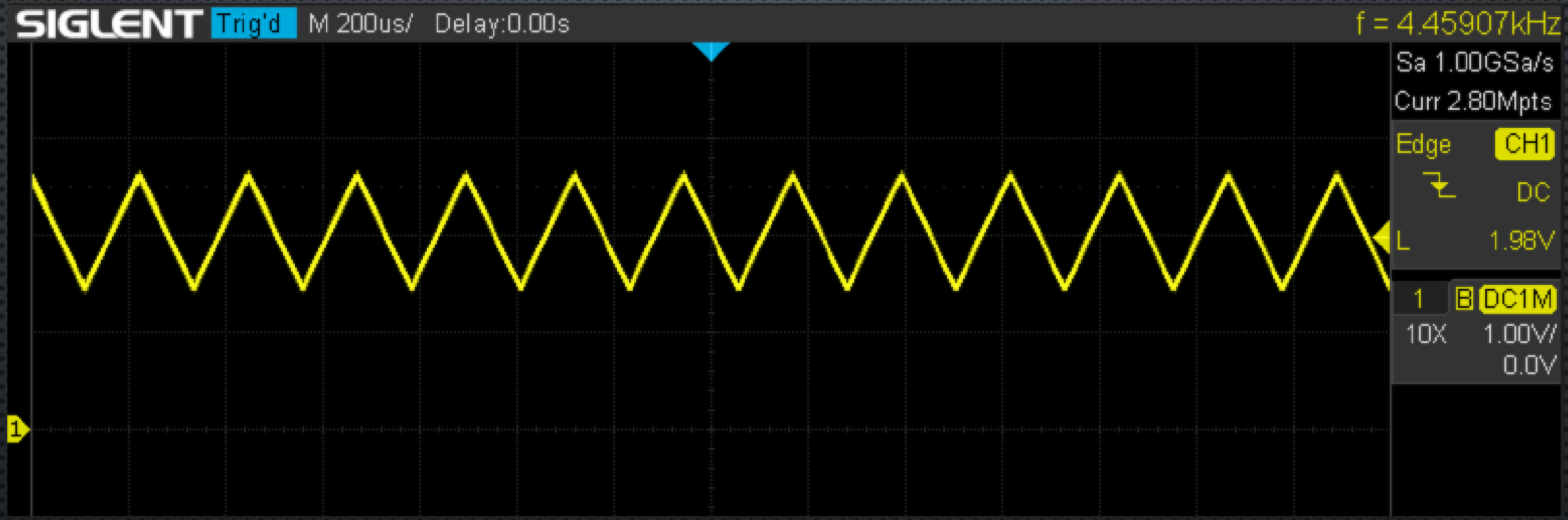

```
Result: Sine          Percents: Sine=85.9%, Square=9.3%, Triangle=5.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Sine          Percents: Sine=79.6%, Square=16.4%, Triangle=3.9%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Triangle      Percents: Sine=37.1%, Square=1.1%, Triangle=51.1%, Sawtooth=10.5%, Noise=0.0%, EKG=0.0%
Result: Sine          Percents: Sine=71.4%, Square=6.6%, Triangle=19.9%, Sawtooth=1.9%, Noise=0.0%, EKG=0.0%
Result: Sine          Percents: Sine=87.8%, Square=7.0%, Triangle=5.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Sine          Percents: Sine=57.0%, Square=41.4%, Triangle=1.5%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
```

TRÓJKĄT 1.4 KHZ



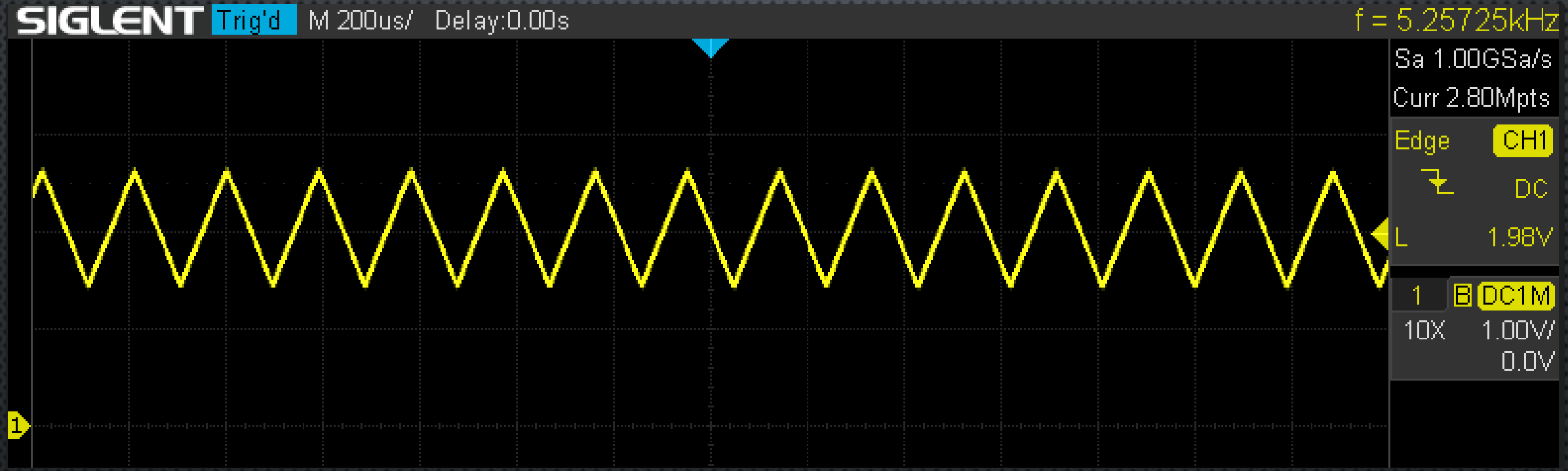

```
Result: Triangle        Percents: Sine=12.5%, Square=0.0%, Triangle=85.1%, Sawtooth=2.3%, Noise=0.0%, EKG=0.0%
Result: Triangle        Percents: Sine=14.8%, Square=0.0%, Triangle=83.9%, Sawtooth=1.1%, Noise=0.0%, EKG=0.0%
Result: Sine            Percents: Sine=50.0%, Square=0.0%, Triangle=50.0%, Sawtooth=0.3%, Noise=0.0%, EKG=0.0%
Result: Triangle        Percents: Sine=27.7%, Square=0.0%, Triangle=71.4%, Sawtooth=0.7%, Noise=0.0%, EKG=0.0%
Result: Triangle        Percents: Sine=21.4%, Square=0.0%, Triangle=76.1%, Sawtooth=2.3%, Noise=0.0%, EKG=0.0%
Result: Triangle        Percents: Sine=45.7%, Square=0.0%, Triangle=53.5%, Sawtooth=1.1%, Noise=0.0%, EKG=0.0%
Result: Triangle        Percents: Sine=33.9%, Square=0.0%, Triangle=64.0%, Sawtooth=1.5%, Noise=0.0%, EKG=0.0%
Result: Triangle        Percents: Sine=37.8%, Square=0.0%, Triangle=60.9%, Sawtooth=1.1%, Noise=0.0%, EKG=0.0%
Result: Triangle        Percents: Sine=27.3%, Square=0.0%, Triangle=71.0%, Sawtooth=1.5%, Noise=0.0%, EKG=0.0%
Result: Triangle        Percents: Sine=19.1%, Square=0.0%, Triangle=79.6%, Sawtooth=1.1%, Noise=0.0%, EKG=0.0%
Result: Triangle        Percents: Sine=41.7%, Square=0.0%, Triangle=57.8%, Sawtooth=0.3%, Noise=0.0%, EKG=0.0%
Result: Triangle        Percents: Sine=24.2%, Square=0.0%, Triangle=73.8%, Sawtooth=1.9%, Noise=0.0%, EKG=0.0%
```

TRÓJKĄT 4.5 KHZ



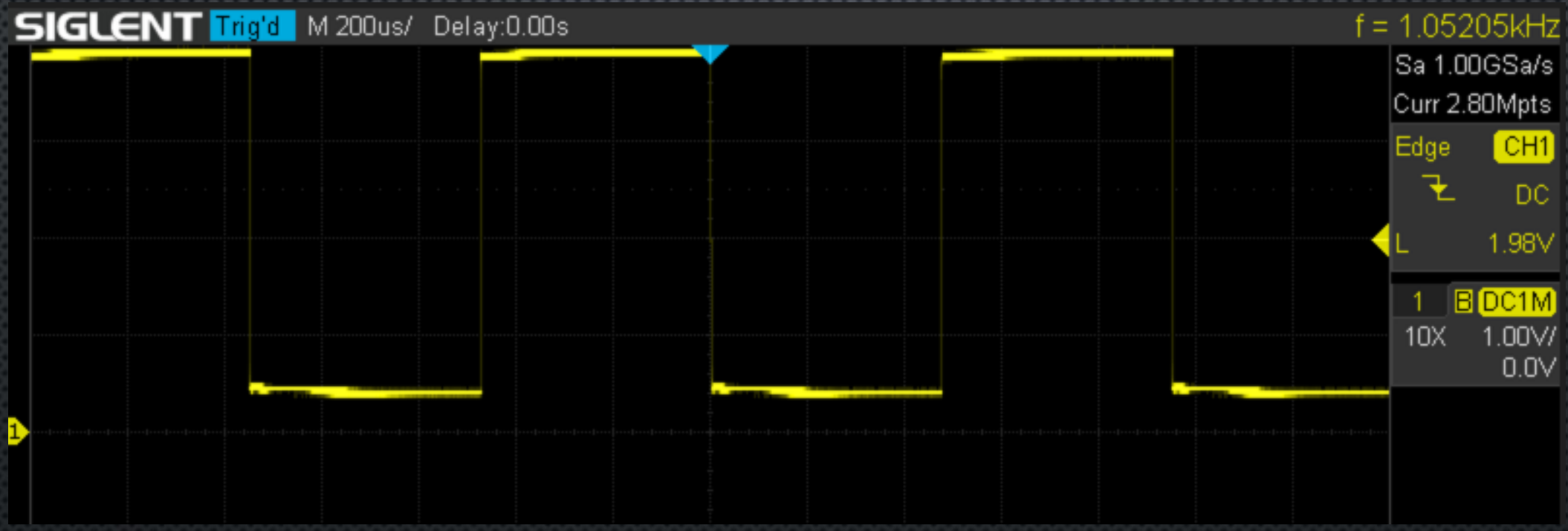

```
Result: Triangle          Percents: Sine=21.4%, Square=0.0%, Triangle=76.9%, Sawtooth=1.5%, Noise=0.0%, EKG=0.0%
Result: Triangle          Percents: Sine=45.7%, Square=0.0%, Triangle=53.9%, Sawtooth=0.3%, Noise=0.0%, EKG=0.0%
Result: Triangle          Percents: Sine=14.4%, Square=0.0%, Triangle=82.8%, Sawtooth=2.3%, Noise=0.0%, EKG=0.0%
Result: Triangle          Percents: Sine=8.2%, Square=0.0%, Triangle=88.2%, Sawtooth=3.5%, Noise=0.0%, EKG=0.0%
Result: Sine              Percents: Sine=53.5%, Square=0.0%, Triangle=45.7%, Sawtooth=0.3%, Noise=0.0%, EKG=0.0%
Result: Triangle          Percents: Sine=27.7%, Square=0.0%, Triangle=71.4%, Sawtooth=0.7%, Noise=0.0%, EKG=0.0%
Result: Triangle          Percents: Sine=41.7%, Square=0.0%, Triangle=57.4%, Sawtooth=0.7%, Noise=0.0%, EKG=0.0%
```

TRÓJKĄT 5.25 KHZ (POZA ZAKRESEM)



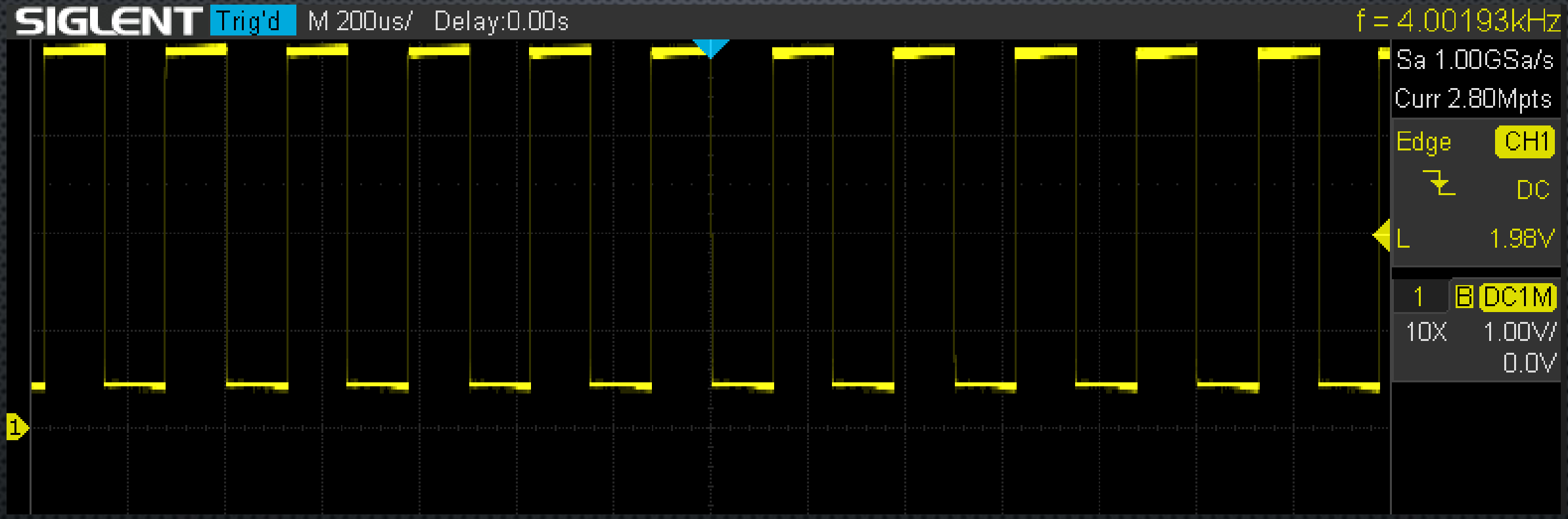

```
Result: Sawtooth          Percents: Sine=0.0%, Square=0.0%, Triangle=0.3%, Sawtooth=80.0%, Noise=0.0%, EKG=19.1%
Result: EKG               Percents: Sine=0.0%, Square=0.0%, Triangle=0.0%, Sawtooth=37.8%, Noise=1.1%, EKG=60.9%
Result: EKG               Percents: Sine=0.0%, Square=0.0%, Triangle=0.0%, Sawtooth=24.6%, Noise=1.1%, EKG=74.6%
Result: Sawtooth          Percents: Sine=0.0%, Square=0.0%, Triangle=0.0%, Sawtooth=53.9%, Noise=0.0%, EKG=46.0%
Result: EKG               Percents: Sine=0.0%, Square=0.0%, Triangle=0.0%, Sawtooth=34.3%, Noise=0.7%, EKG=64.8%
Result: EKG               Percents: Sine=0.0%, Square=0.0%, Triangle=0.0%, Sawtooth=30.8%, Noise=0.7%, EKG=68.3%
Result: EKG               Percents: Sine=0.0%, Square=0.0%, Triangle=0.0%, Sawtooth=27.7%, Noise=0.7%, EKG=71.4%
Result: EKG               Percents: Sine=0.0%, Square=0.0%, Triangle=0.0%, Sawtooth=19.1%, Noise=0.3%, EKG=80.4%
Result: EKG               Percents: Sine=0.0%, Square=0.0%, Triangle=0.0%, Sawtooth=19.1%, Noise=1.1%, EKG=79.6%
```

PROSTOKĄT 1KHZ




```
Result: Square          Percents: Sine=5.4%, Square=94.5%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=4.6%, Square=95.3%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=8.5%, Square=91.4%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=2.3%, Square=97.6%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=7.4%, Square=92.5%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=2.3%, Square=97.6%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=1.1%, Square=98.8%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=1.5%, Square=98.4%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
```

PROSTOKĄT 4 KHZ




```
Result: Square          Percents: Sine=4.6%, Square=95.3%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=4.6%, Square=95.3%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=4.6%, Square=95.3%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=2.3%, Square=97.6%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=3.9%, Square=96.0%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=8.5%, Square=91.4%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
Result: Square          Percents: Sine=1.9%, Square=98.0%, Triangle=0.0%, Sawtooth=0.0%, Noise=0.0%, EKG=0.0%
```

Projekt przygotowali:

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