Analyze Märklin track signal

Get MM2 signal from track

Load file

```
Directory[]
```

```
/home/cmaier/scad/Maerklin/analysis
```

```
Dimensions[raw = Import["MM2.78.fwd.csv"]]
```

```
{1048578, 3}
```

```
Take[raw, 12]
```

```
{{X, CH1, }, {Second, Volt, }, {-0.0589688, -17.2, },
 {-0.0589687, -17.2, }, {-0.0589686, -17.2, }, {-0.0589685, -17.2, },
 {-0.0589684, -17.2, }, {-0.0589683, -17.2, }, {-0.0589682, -17.2, },
 {-0.0589681, -17.2, }, {-0.058968, -17.2, }, {-0.0589679, -17.2, }}
```

Convert into time series

```
Dimensions[timeseries = Most /@ Drop[raw, 2]]
```

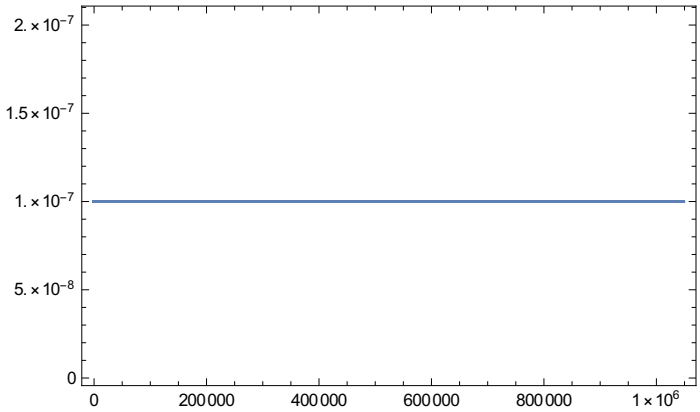
```
{1048576, 2}
```

Calculate time step

```
Dimensions[ListConvolve[{1, -1}, First /@ #] &[timeseries]]
```

```
{1048575}
```

```
ListPlot[ListConvolve[{1, -1}, First /@ #], Frame → True, PlotRange → All] &[
 timeseries]
```



```
{Min[#], Max[#]} &[ListConvolve[{1, -1}, First /@ #]] &[timeseries]
```

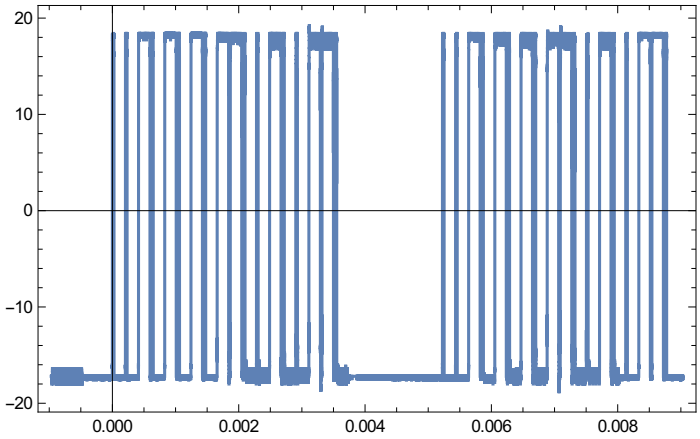
$\{1. \times 10^{-7}, 1. \times 10^{-7}\}$

```
timestep = Median[ListConvolve[{1, -1}, First /@ #]] &[timeseries]
```

$1. \times 10^{-7}$

Display

```
ListPlot[Take[#, {580 000, 680 000}] &[timeseries], Frame → True, Joined → True]
```



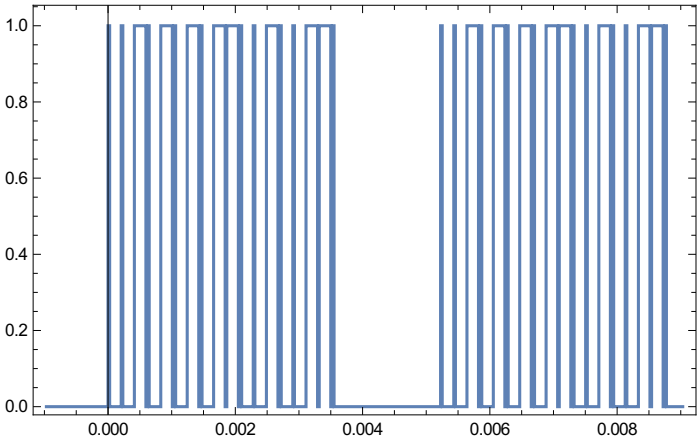
Digitize time series

```
Dimensions[digitized = Map[{#[[1]], HeavisideTheta[#[[2]] - 0.0001]} &, timeseries, {1}]]
```

{1 048 576, 2}

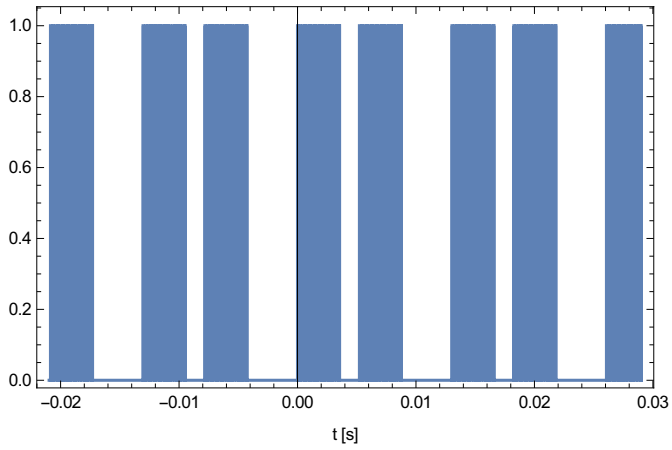
Display

```
ListPlot[Take[#, {580 000, 680 000}] &[digitized], Frame → True, Joined → True]
```



Display 50ms data transmission

```
ListPlot[Take[#, {380 000, 880 000}] & /@ MapThread[
   Function[{series, offset}, # + {0, offset} & /@ series], {{digitized}, {0}}],
 Frame → True, Joined → True, PlotRange → All, FrameLabel → {"t [s]", ""}]
```



Runs of identical values for series

```
Map[Dimensions, runs = SplitBy[#, Last] &[digitized], {1}]
```

```
{{679, 2}, {1813, 2}, {263, 2}, {1812, 2}, {264, 2}, {263, 2}, {16 743, 2}, {257, 2},
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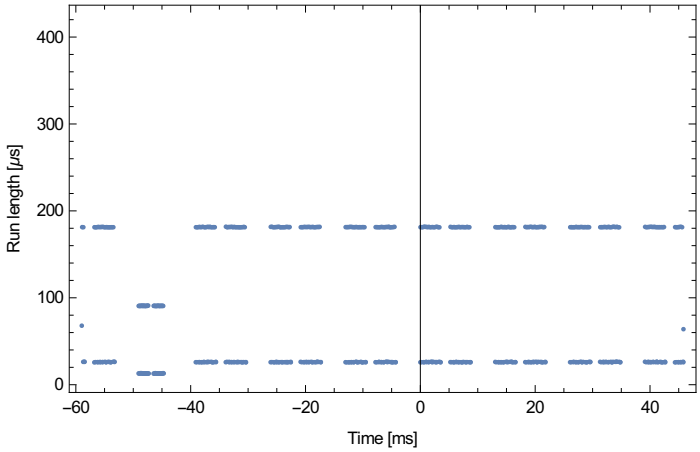
{1816, 2}, {259, 2}, {260, 2}, {1817, 2}, {1812, 2}, {264, 2}, {258, 2}, {639, 2}}

```
Length[runs]
```

599

```
ListPlot[{10^3 First[First[#]], 10^6 timestep Length[#]} & /@ #,
    Frame → True, FrameLabel → {"Time [ms]", "Run length [μs]"}] &[runs]
```



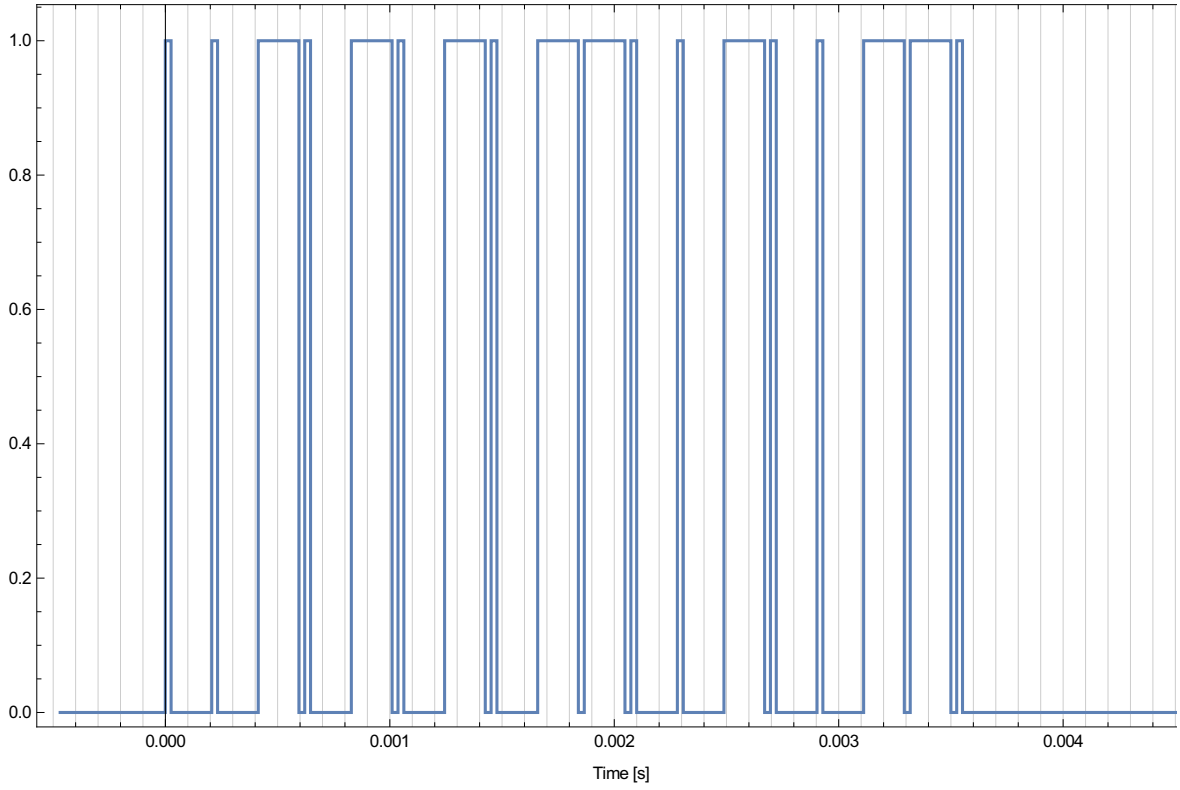
There is one outlier in the MM2 packet sequence ... maybe a switch packet?

Packets within the time series

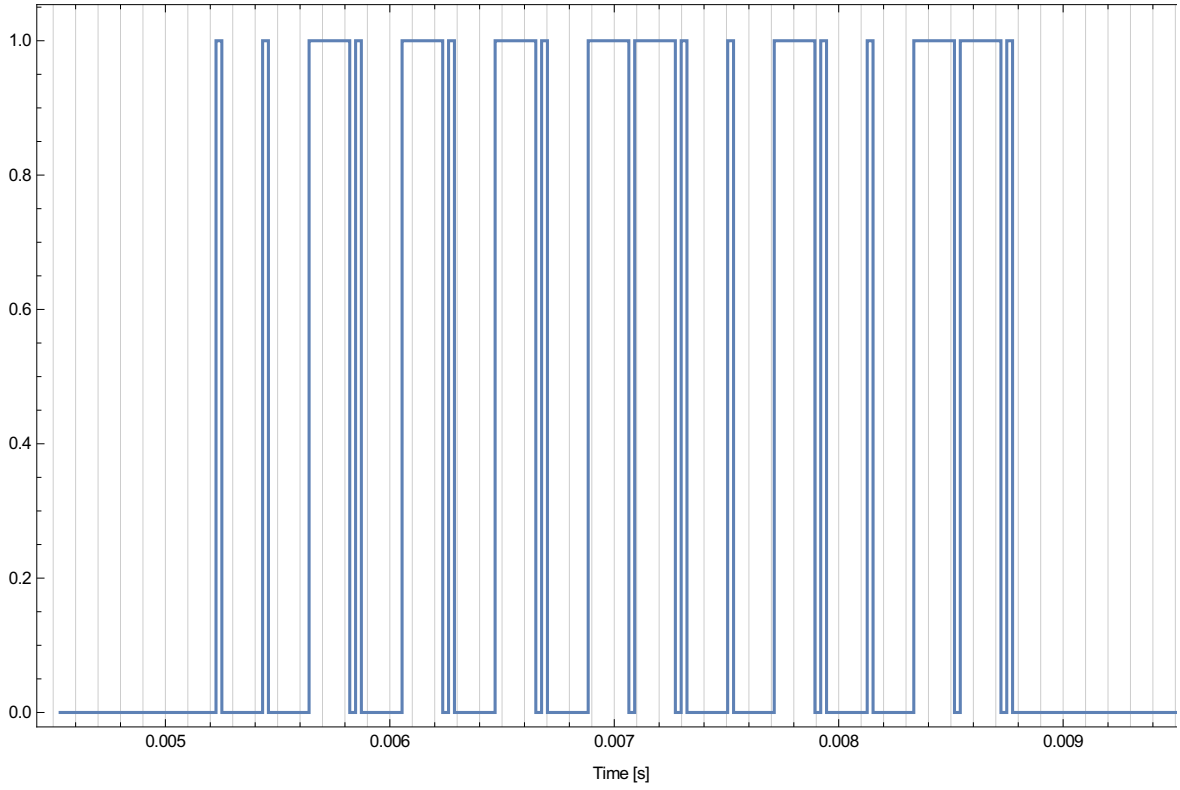
Short data packets

MM format, see 2.2.9 Einbettung von Steuerbefehlen im MM-Format


```
ListPlot[Take[#, {585 000, 635 000}],
    Frame → True, Joined → True, FrameLabel → {"Time [s]", ""},
    GridLines → {Range[-.15, .15, 1.*^-4], None}] &[digitized]
```



```
ListPlot[Take[#, {635 000, 685 000}],
    Frame → True, Joined → True, FrameLabel → {"Time [s]", ""},
    GridLines → {Range[-.15, .15, 1.*^-4], None}] &[digitized]
```



Run length decoding

bit frame (100μs) per sampling step

$$\frac{\text{timestep}}{10^{-4}}$$

```
0.001
```

Get run lengths of full trace

```
Length[fullruns = SplitBy[#, Last] &[digitized]]
```

```
599
```

Run lengths in bit frames

$$\text{rlbits} = \text{Map}\left[\frac{\text{timestep}}{10^{-4}}\,\text{Length}[\#]\,\&,\ \text{fullruns},\ \{1\}\right]$$

```
{0.679, 1.813, 0.263, 1.812, 0.264, 0.263, 16.743, 0.257, 1.812, 0.26, 1.811, 1.812,
 0.259, 0.26, 1.815, 1.814, 0.262, 0.258, 1.813, 1.815, 0.26, 0.26, 1.816, 1.813,
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```

0.907, 0.13, 0.91, 0.129, 0.13, 0.906, 0.13, 0.905, 0.129, 0.907, 0.129, 0.907,
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1.812, 0.265, 0.262, 1.813, 0.258, 1.812, 1.813, 0.263, 1.812, 0.259, 0.259,
1.813, 0.258, 1.812, 1.814, 0.264, 0.257, 16.745, 0.257, 1.813, 0.259, 1.812,
1.812, 0.26, 0.258, 1.813, 1.816, 0.259, 0.26, 1.817, 1.812, 0.264, 0.258, 0.639}

Run length encoded data packets separated by run length >2 bits

```
rlruns = SplitBy[#, # > 2 &] &[rlbits]
```

```
{{0.679, 1.813, 0.263, 1.812, 0.264, 0.263}, {16.743},
 {0.257, 1.812, 0.26, 1.811, 1.812, 0.259, 0.26, 1.815, 1.814, 0.262, 0.258, 1.813,
  1.815, 0.26, 0.26, 1.816, 1.813, 0.263, 1.811, 0.26, 0.258, 1.813, 1.812, 0.264,
  1.811, 0.26, 1.811, 0.259, 0.259, 1.812, 1.812, 0.264, 1.812, 0.264, 0.262},
 {41.633}, {0.13, 0.906, 0.128, 0.907, 0.907, 0.13, 0.133, 0.905, 0.908, 0.133,
  0.13, 0.907, 0.91, 0.129, 0.13, 0.905, 0.907, 0.13, 0.91, 0.129, 0.13, 0.906, 0.13,
  0.905, 0.129, 0.907, 0.129, 0.907, 0.128, 0.907, 0.128, 0.908, 0.129, 0.911, 0.129},
 {8.365}, {0.128, 0.907, 0.128, 0.908, 0.906, 0.133, 0.13, 0.906, 0.906, 0.129, 0.13,
  0.906, 0.906, 0.13, 0.128, 0.908, 0.909, 0.131, 0.905, 0.131, 0.128, 0.907, 0.129,
  0.906, 0.129, 0.907, 0.128, 0.907, 0.129, 0.906, 0.129, 0.908, 0.133, 0.906, 0.13},
 {55.661}, {0.259, 1.812, 0.259, 1.812, 1.812, 0.259, 0.26, 1.816, 1.812, 0.259, 0.258,
  1.814, 1.817, 0.263, 0.258, 1.812, 1.812, 0.259, 1.813, 0.263, 0.26, 1.817, 0.262,
  1.813, 1.817, 0.263, 1.811, 0.26, 0.258, 1.812, 0.258, 1.813, 1.812, 0.263, 0.26},
 {16.744}, {0.259, 1.818, 0.263, 1.811, 1.814, 0.263, 0.258, 1.814, 1.815, 0.26, 0.259,
  1.817, 1.811, 0.26, 0.26, 1.816, 1.812, 0.259, 1.812, 0.26, 0.262, 1.812, 0.26,
  1.812, 1.811, 0.26, 1.812, 0.258, 0.259, 1.812, 0.26, 1.816, 1.812, 0.26, 0.257},
 {42.637}, {0.259, 1.816, 0.26, 1.817, 1.812, 0.259, 0.258, 1.812, 1.813, 0.264, 0.257,
  1.814, 1.816, 0.259, 0.259, 1.817, 1.811, 0.26, 1.811, 0.259, 0.259, 1.812, 1.812,
  0.259, 1.812, 0.26, 1.815, 0.259, 0.26, 1.816, 0.259, 1.812, 1.814, 0.263, 0.258},
 {16.74}, {0.263, 1.812, 0.259, 1.813, 1.812, 0.259, 0.26, 1.816, 1.814, 0.263, 0.258,
  1.814, 1.815, 0.26, 0.26, 1.816, 1.813, 0.263, 1.813, 0.258, 0.26, 1.816, 1.812,
  0.259, 1.812, 0.259, 1.813, 0.264, 0.262, 1.815, 0.262, 1.814, 1.816, 0.259, 0.26},
 {42.639}, {0.259, 1.813, 0.257, 1.813, 1.813, 0.258, 0.259, 1.814, 1.816, 0.258, 0.26,
  1.816, 1.812, 0.259, 0.259, 1.813, 1.812, 0.265, 1.815, 0.26, 0.258, 1.812, 0.259,
  1.812, 1.813, 0.263, 1.812, 0.259, 0.258, 1.813, 0.258, 1.813, 1.812, 0.26, 0.259},
 {16.742}, {0.259, 1.813, 0.258, 1.813, 1.812, 0.26, 0.263, 1.812, 1.812, 0.259, 0.26,
  1.816, 1.812, 0.259, 0.259, 1.813, 1.812, 0.265, 1.815, 0.261, 0.262, 1.814, 0.263,
  1.818, 1.81, 0.26, 1.812, 0.26, 0.259, 1.812, 0.258, 1.814, 1.816, 0.259, 0.259},
 {42.638}, {0.258, 1.812, 0.259, 1.813, 1.812, 0.259, 0.259, 1.818, 1.816, 0.263, 0.26,
  1.816, 1.812, 0.26, 0.26, 1.816, 1.812, 0.264, 1.812, 0.264, 0.258, 1.814, 0.263,
  1.812, 1.812, 0.259, 0.26, 1.816, 0.26, 1.817, 1.812, 0.264, 1.811, 0.26, 0.258},
 {16.739}, {0.26, 1.816, 0.259, 1.812, 1.812, 0.26, 0.257, 1.814, 1.811, 0.26, 0.263,
  1.812, 1.813, 0.258, 0.26, 1.816, 1.812, 0.259, 1.813, 0.259, 0.258, 1.814, 0.262,
  1.813, 1.812, 0.259, 0.259, 1.812, 0.26, 1.816, 1.812, 0.259, 1.812, 0.259, 0.259},
 {42.636}, {0.262, 1.813, 0.259, 1.812, 1.811, 0.26, 0.258, 1.812, 1.812, 0.259, 0.259,
  1.817, 1.812, 0.259, 0.258, 1.812, 1.814, 0.263, 1.811, 0.26, 0.263, 1.812, 0.26,
  1.817, 1.812, 0.264, 1.81, 0.261, 0.263, 1.813, 0.257, 1.813, 1.812, 0.26, 0.259},
 {16.741}, {0.26, 1.816, 0.258, 1.812, 1.814, 0.263, 0.258, 1.813, 1.816, 0.259, 0.259,
  1.817, 1.812, 0.264, 0.258, 1.813, 1.817, 0.264, 1.811, 0.26, 0.258, 1.813, 0.263,
  1.812, 1.816, 0.262, 1.815, 0.259, 0.26, 1.817, 0.258, 1.812, 1.814, 0.263, 0.258},
 {42.643}, {0.259, 1.812, 0.259, 1.813, 1.811, 0.26, 0.263, 1.812, 1.812, 0.259, 0.26,
  1.816, 1.812, 0.259, 0.259, 1.813, 1.812, 0.265, 1.815, 0.259, 0.259, 1.814, 0.262,
  1.812, 1.813, 0.259, 1.813, 0.259, 0.258, 1.812, 1.814, 0.263, 1.812, 0.26, 0.263},
 {16.737}, {0.263, 1.812, 0.259, 1.813, 1.812, 0.264, 0.257, 1.814,
  1.815, 0.261, 0.262, 1.813, 1.812, 0.259, 0.26, 1.817, 1.812,
```

```
  0.263, 1.812, 0.26, 0.257, 1.814, 0.263, 1.818, 1.816, 0.263, 1.813,
  0.264, 0.264, 1.817, 1.812, 0.263, 1.811, 0.26, 0.258}, {42.645},
 {0.264, 1.816, 0.259, 1.812, 1.813, 0.264, 0.257, 1.814, 1.816, 0.259, 0.26,
  1.817, 1.815, 0.261, 0.262, 1.814, 1.817, 0.259, 1.812, 0.265, 0.262, 1.813, 0.258,
  1.812, 1.813, 0.263, 1.812, 0.259, 0.259, 1.813, 0.258, 1.812, 1.814, 0.264, 0.257},
 {16.745}, {0.257, 1.813, 0.259, 1.812, 1.812, 0.26, 0.258, 1.813,
  1.816, 0.259, 0.26, 1.817, 1.812, 0.264, 0.258, 0.639}}
```

```
Dimensions[rlruns]
```

```
{35}
```

```
Map[Length, rlruns, {1}]
```

```
{6, 1, 35, 1, 35, 1, 35, 1, 35, 1, 35, 1, 35, 1, 35, 1,
 35, 1, 35, 1, 35, 1, 35, 1, 35, 1, 35, 1, 35, 1, 35, 1, 16}
```

Length of packet separators in 100μs bit frames

```
TableForm[Select[#, Length[#] ≤ 1 &] &[rlruns]]
```

```
16.743
41.633
8.365
55.661
16.744
42.637
16.74
42.639
16.742
42.638
16.739
42.636
16.741
42.643
16.737
42.645
16.745
```

Run length encoded packets

Display number of runs per packet

```
TableForm[Map[Length, packetruns = Select[#, Length[#] > 1 &] &[rlruns], {1}]]
```

```
6
35
35
35
35
35
35
35
35
35
35
35
35
35
35
35
35
16
```

Runs in 12.5μs time unit multiples

```
RoundRunTime = Round[8 #] &
```

```
Round[8 #1] &
```

```
MatrixForm[
 Transpose[mmruns = RoundRunTime[Select[#, Length[#] == 35 &] &[packetruns]]]]
```

2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
14	7	7	14	15	15	14	15	15	14	15	15	15	14	14	15
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
14	7	7	14	14	15	15	15	15	15	14	14	14	15	15	14
14	7	7	14	15	14	14	15	14	14	14	14	15	14	14	15
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
15	7	7	15	15	14	15	15	14	15	15	14	15	14	15	15
15	7	7	14	15	15	15	15	14	15	14	14	15	14	15	15
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
15	7	7	15	15	15	15	15	15	15	14	15	15	15	15	15
15	7	7	15	14	15	15	14	14	14	15	14	14	14	14	15
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
15	7	7	14	15	15	15	15	15	15	15	14	15	15	15	15
15	7	7	14	14	14	15	14	14	14	14	15	15	14	14	15
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
14	7	7	15	14	14	15	15	15	14	15	14	14	15	14	14
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
15	7	7	15	14	14	15	14	15	15	15	14	15	15	15	15
14	1	1	2	2	14	14	2	2	2	2	2	2	2	2	2
2	7	7	15	14	2	2	14	15	14	15	15	14	14	15	14
14	1	1	15	14	14	14	15	14	14	14	14	15	15	15	15
2	7	7	2	2	2	2	2	2	2	2	2	2	2	2	2
14	1	1	14	14	15	15	14	14	2	2	14	15	15	15	14
2	7	7	2	2	2	2	2	2	15	14	2	2	2	2	2
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
14	7	7	14	14	15	15	15	14	15	15	15	15	14	15	15
14	1	1	2	2	2	2	2	2	14	14	2	2	15	14	2
2	7	7	15	15	14	15	15	15	2	2	15	14	2	2	14
14	1	1	14	14	15	15	14	15	14	14	14	15	14	14	15
2	7	7	2	2	2	2	2	2	2	2	2	2	2	2	2
2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2

Truncated runs

```
truncruns = RoundRunTime[
   Select[#, Function[l, And @@ (l ≠ # & /@ {1, 35, 77, 191})][Length[#]] &] &[
    packetruns]]
```

```
{{5, 15, 2, 14, 2, 2}, {2, 15, 2, 14, 14, 2, 2, 15, 15, 2, 2, 15, 14, 2, 2, 5}}
```

Parse runs

Shotgun MM parser

for locomotives

```
MMparser = Function[{in, out},
  If[Length[in] ≥ 2,
   Which[Take[in, 2] == {2, 14} ∨ Take[in, 2] == {2, 15}, {Drop[in, 2], Append[out, 0]},
    Take[in, 2] == {14, 2} ∨ Take[in, 2] == {15, 2}, {Drop[in, 2], Append[out, 1]},
    True, {Drop[in, 1], Append[out, ⚠]}],
   If[Length[in] == 1, Which[{2} == Take[in, 1], {Drop[in, 1], Append[out, 0]},
     Take[in, 1] == {14} ∨ Take[in, 1] == {15}, {Drop[in, 1], Append[out, 1]},
     True, {Drop[in, 1], Append[out, ⚠]}], {Drop[in, 1], Append[out, ⚠]}]]
 ]
```

```
Function[{in, out},
 If[Length[in] ≥ 2, Which[Take[in, 2] == {2, 14} || Take[in, 2] == {2, 15},
   {Drop[in, 2], Append[out, 0]}, Take[in, 2] == {14, 2} || Take[in, 2] == {15, 2},
   {Drop[in, 2], Append[out, 1]}, True, {Drop[in, 1], Append[out, ⚠]}],
  If[Length[in] == 1, Which[{2} == Take[in, 1], {Drop[in, 1], Append[out, 0]},
    Take[in, 1] == {14} || Take[in, 1] == {15}, {Drop[in, 1], Append[out, 1]},
    True, {Drop[in, 1], Append[out, ⚠]}], {Drop[in, 1], Append[out, ⚠]}]]]
```

for magnets

```
MMmagparser = Function[{in, out}, If[Length[in] ≥ 2,
   Which[{1, 7} == Take[in, 2], {Drop[in, 2], Append[out, 0]}, {7, 1} == Take[in, 2],
    {Drop[in, 2], Append[out, 1]}, True, {Drop[in, 1], Append[out, ⚠]}],
   If[Length[in] == 1, Which[{1} == Take[in, 1], {Drop[in, 1], Append[out, 0]},
     {7} == Take[in, 1], {Drop[in, 1], Append[out, 1]}, True,
     {Drop[in, 1], Append[out, ⚠]}], {Drop[in, 1], Append[out, ⚠]}]]]
```

```
Function[{in, out}, If[Length[in] ≥ 2,
  Which[{1, 7} == Take[in, 2], {Drop[in, 2], Append[out, 0]}, {7, 1} == Take[in, 2],
   {Drop[in, 2], Append[out, 1]}, True, {Drop[in, 1], Append[out, ⚠]}],
  If[Length[in] == 1, Which[{1} == Take[in, 1], {Drop[in, 1], Append[out, 0]},
    {7} == Take[in, 1], {Drop[in, 1], Append[out, 1]}, True,
    {Drop[in, 1], Append[out, ⚠]}], {Drop[in, 1], Append[out, ⚠]}]]]
```

Parse by iteration over run length encoded input

```
NestWhile[MMparser @@ # &, {mmruns[[1]], {}}, Length[First[#]] > 0 &]
```

```
{{}, {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1, 1, 1, 0, 1, 1, 0}}
```

Apply parsers

Parse over MM runs

```
mmbitsequences =
 Map[Last[NestWhile[MMparser @@ # &, {#, {}}, Length[First[#]] > 0 &]] &, mmruns, {1}]
```

```
{{0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1, 1, 1, 0, 1, 1, 0}, {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠},
 {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠}, {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1, 1, 1, 0, 0, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1, 1, 1, 0, 0, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 1, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 1, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 0}}
```

```
mmmagbitsequences = Map[
  Last[NestWhile[MMmagparser @@ # &, {#, {}}, Length[First[#]] > 0 &]] &, mmruns, {1}]
```

```
{{⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠}, {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0}, {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠},
 {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠}, {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠},
 {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠}, {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠},
 {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠}, {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠},
 {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠}, {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠},
 {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠}, {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠}}
```

Parse over truncated runs

```
Map[Last[NestWhile[MMparser @@ # &, {#, {}}, Length[First[#]] > 0 &]] &, truncruns, {1}]
```

```
{{⚠, 1, 1, 0}, {0, 0, 1, 0, 1, 0, 1, ⚠, ⚠}}
```

Eliminate duplicate sequences

It turns out in this case that there is only few packets, which are repeated

```
mmbitseq = Union[mmbitsequences]
```

```
{{0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 1, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1, 1, 1, 0, 0, 1, 0},
 {0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1, 1, 1, 0, 1, 1, 0}, {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠}}
```

```
mmmagbitseq = Union[mmmagbitsequences]
```

```
{{0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0}, {⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠,
  ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠, ⚠}}
```

Decode MM packets

Motorola format bit

```
mmbit = Function[{in, out}, If[Length[in] < 2, {Drop[in], Append[out, ERROR]},
    {Drop[in, 2], Append[out, Switch[Take[in, 2], {0, 0}, 0, {1, 1}, 1, _, ⚠]]}]]
```

```
Function[{in, out}, If[Length[in] < 2,
  {Drop[in], Append[out, ERROR]}, {Drop[in, 2], Append[out, Switch[Take[in, 2],
     {0, 0}, 0,
     {1, 1}, 1,
     _, ⚠]]}]]
```

Motorola format trit

```
mmtrit = Function[{in, out},
  If[Length[in] < 2, {Drop[in], Append[out, ERROR]}, {Drop[in, 2],
    Append[out, Switch[Take[in, 2], {0, 0}, 0, {1, 1}, 1, {1, 0}, 2, _, ⚠]]}
  ]
 ]
```

```
Function[{in, out}, If[Length[in] < 2,
  {Drop[in], Append[out, ERROR]}, {Drop[in, 2], Append[out, Switch[Take[in, 2],
     {0, 0}, 0,
     {1, 1}, 1,
     {1, 0}, 2,
     _, ⚠]]}]]
```

Motorola format 4-trit address (address 80, all open, is unassigned)

```
mmaddress = Function[{in, out}, If[Length[in] < 8, {Drop[in], Append[out, ERROR]},
    ({#1[[1]], Append[out, {ADDR, FromDigits[Reverse[Last[#1]], 3]}]} &)[
     Nest[mmtrit @@ #1 &, {in, out}, 4]]]]
```

```
Function[{in, out}, If[Length[in] < 8, {Drop[in], Append[out, ERROR]},
  ({#1[[1]], Append[out, {ADDR, FromDigits[Reverse[Last[#1]], 3]}]} &)[
   Nest[mmtrit @@ #1 &, {in, out}, 4]]]]
```

```
mmaddress[mmbitseq[[1]], {}]
```

```
{{1, 1, 0, 0, 1, 0, 0, 1, 1, 0}, {{ADDR, 78}}}
```

Motorola format parser

4-trit address, one function (double) bit, 4 velocity (double) bits

MM1 format

```
mm1parse =
 Function[{in, out},
  ({#1, Append[Drop[#2, -4], {SPEED, FromDigits[Reverse[Take[#2, -4]], 2]}]} &) @@
   Nest[mmbit @@ #1 &, ({#1[[1]], Append[Most[#1[[2]]], {FUNC, Last[#1[[2]]]}]} &)[
     mmbit @@ mmaddress[in, out]], 4]]
```

```
Function[{in, out},
 ({#1, Append[Drop[#2, -4], {SPEED, FromDigits[Reverse[Take[#2, -4]], 2]}]} &) @@
  Nest[mmbit @@ #1 &, ({#1[[1]], Append[Most[#1[[2]]], {FUNC, Last[#1[[2]]]}]} &)[
    mmbit @@ mmaddress[in, out]], 4]]
```

MM2 format

```
mm2dataparse = Function[{in, out}, If[8 ≠ Length[in], {in, Append[out, ERROR]},
    Block[{speed = FromDigits[in[[{7, 5, 3, 1}]], 2],
      data = in[[{2, 4, 6, 8}]], tag}, tag = Which[
       data == {1, 0, 1, 0} ∧ speed > 7, {REVERSE},
       data == {1, 0, 1, 1} ∧ speed < 8, {REVERSE},
       data == {0, 1, 0, 1} ∧ speed < 8, {FORWARD},
       data == {0, 1, 0, 0} ∧ speed > 7, {FORWARD},
       True, {DATA, data}];
     {Drop[in, 8], Join[out, {{SPEED, speed}, tag}]}
    ]
   ]
 ]
```

```
Function[{in, out}, If[8 ≠ Length[in], {in, Append[out, ERROR]},
  Block[{speed = FromDigits[in[[{7, 5, 3, 1}]], 2], data = in[[{2, 4, 6, 8}]], tag},
   tag = Which[data == {1, 0, 1, 0} && speed > 7, {REVERSE},
     data == {1, 0, 1, 1} && speed < 8, {REVERSE}, data == {0, 1, 0, 1} && speed < 8,
     {FORWARD}, data == {0, 1, 0, 0} && speed > 7, {FORWARD}, True, {DATA, data}];
   {Drop[in, 8], Join[out, {{SPEED, speed}, tag}]}]]]
```

```
mm2parse =
 Function[{in, out},
  mm2dataparse @@ (({#1[[1]], Append[Most[#1[[2]]], {FUNC, Last[#1[[2]]]}]} &) [
     mmbit @@ mmaddress[in, out]])]
```

```
Function[{in, out}, mm2dataparse @@
  ({#1[[1]], Append[Most[#1[[2]]], {FUNC, Last[#1[[2]]]}]} &)[mmbit @@ mmaddress[in, out]]]
```

Parse Motorola packets

```
Last[mm1parse[#, {}]] & /@ Most[mmbitseq]
```

```
{{{ADDR, 78}, {FUNC, 1}, {SPEED, 14 ◬}}, {{ADDR, 78}, {FUNC, 1}, {SPEED, 2 (1 + 4 ◬)}},
 {{ADDR, 78}, {FUNC, 1}, {SPEED, 2 (1 + 6 ◬)}},
 {{ADDR, 78}, {FUNC, 1}, {SPEED, ◬ + 2 (1 + 4 ◬)}},
 {{ADDR, 78}, {FUNC, 1}, {SPEED, ◬ + 2 (1 + 6 ◬)}}}
```

```
Last[mm2parse[#, {}]] & /@ Most[mmbitseq]
```

```
{{{ADDR, 78}, {FUNC, 1}, {SPEED, 10}, {DATA, {0, 0, 1, 0}}},
 {{ADDR, 78}, {FUNC, 1}, {SPEED, 10}, {FORWARD}},
 {{ADDR, 78}, {FUNC, 1}, {SPEED, 10}, {DATA, {0, 1, 1, 0}}},
 {{ADDR, 78}, {FUNC, 1}, {SPEED, 10}, {DATA, {1, 1, 0, 0}}},
 {{ADDR, 78}, {FUNC, 1}, {SPEED, 10}, {DATA, {1, 1, 1, 0}}}}
```

```
Last[mm1parse[#, {}]] & /@ Most[mmmagbitseq]
```

```
{{{ADDR, 78}, {FUNC, 1}, {SPEED, 0}}}
```