# Talk Outline

## What am I working on and why?

## What did I do last year?

- Rijurekha Sen, Vishal Sevani, Prashima Sharma, Zahir Koradia, Bhaskaran Raman, “Challenges In Communication Assisted Road Transportation Systems for Developing Regions”, NSDR'09, a workshop in SOSP'09, Big Sky, Montana, USA, 11 Oct 2009.

- Rijurekha Sen, Bhaskaran Raman, Prashima Sharma, "Horn-Ok-Please", Mobisys'10, San Francisco, USA, Jun 15-18, 2010.

## What have I done this year?

- [**under submission**] Rijurekha Sen, Pankaj Siriah, Bhaskaran Raman, "RoadSoundSense: Acoustic Sensing Based Road Congestion Monitoring in Developing Regions", SECON'11, Salt Lake City, Utah, USA between June 27-30, 2011.

- Swaroop Roy, Rijurekha Sen, Swanand Kulkarni, Purushottam Kulkarni, Bhaskaran Raman, Lokendra Singh, "WirelessAcrossRoad: RF based Road Traffic Congestion Detection", WISARD'11, a workshop in Comsnets'11, Bangalore, India, Jan 4-5, 2011.

## What will I do next year?

# General Area

Intelligent Transport Systems (ITS) for developing regions.

# Problem Statement Till Now

To find whether a given stretch of road is having
**congested** or **free-flowing** traffic,
at a **low cost**,
**without causing disruption** in traffic flow,
even when **traffic is non-laned and chaotic.**

# Applications

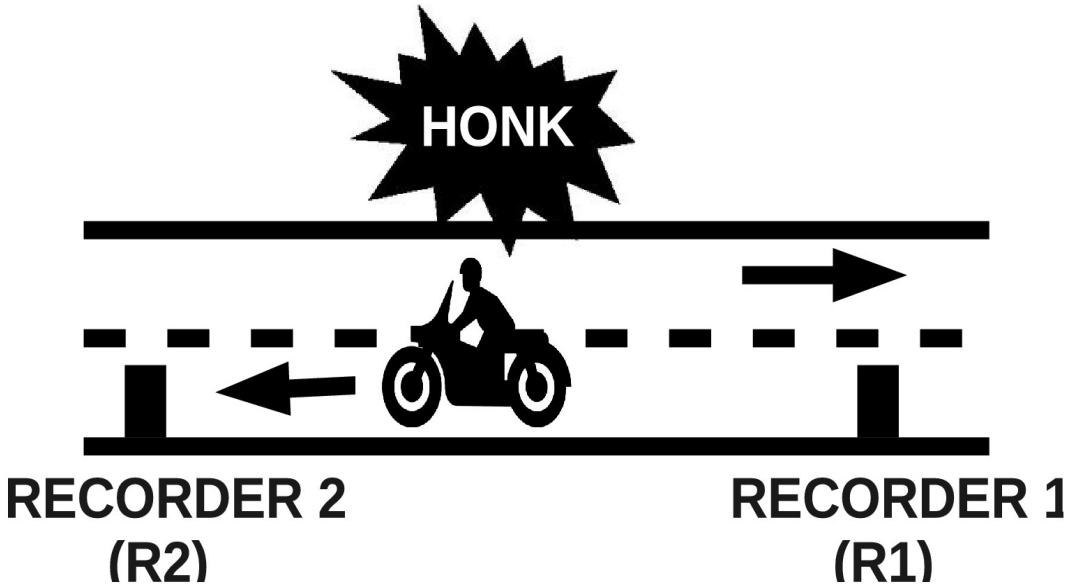
- Traffic light tuning
- Infrastructure planning
- Commuter navigation

# Is This an Unsolved Problem?

| Metric \ Method | Dual loop dectector | Magnetic sensing | Image sensing | GPS in public transport | Smart phones | Acoustic sensing | RF sensing |
|---|---|---|---|---|---|---|---|
| Handles non-laned traffic | no | no | yes | yes | yes | yes | yes |
| Cost (infrastructure/ computation) | high | low | high | low | low | low | low |
| Disruption while installation/ maintenance | yes | yes | no | no | no | no | no |
| Needs commuters' participation | no | no | no | no | yes | yes | no |
| Commuters incur cost | no | no | no | no | yes | no | no |
| Commuters have privacy issues | no | no | no | no | yes | no | no |
| Proliferation in developing countries | low | low | low | low | medium | - | - |

# Horn-Ok-Please

**We can get speed from sound**




**Thanks to Doppler**

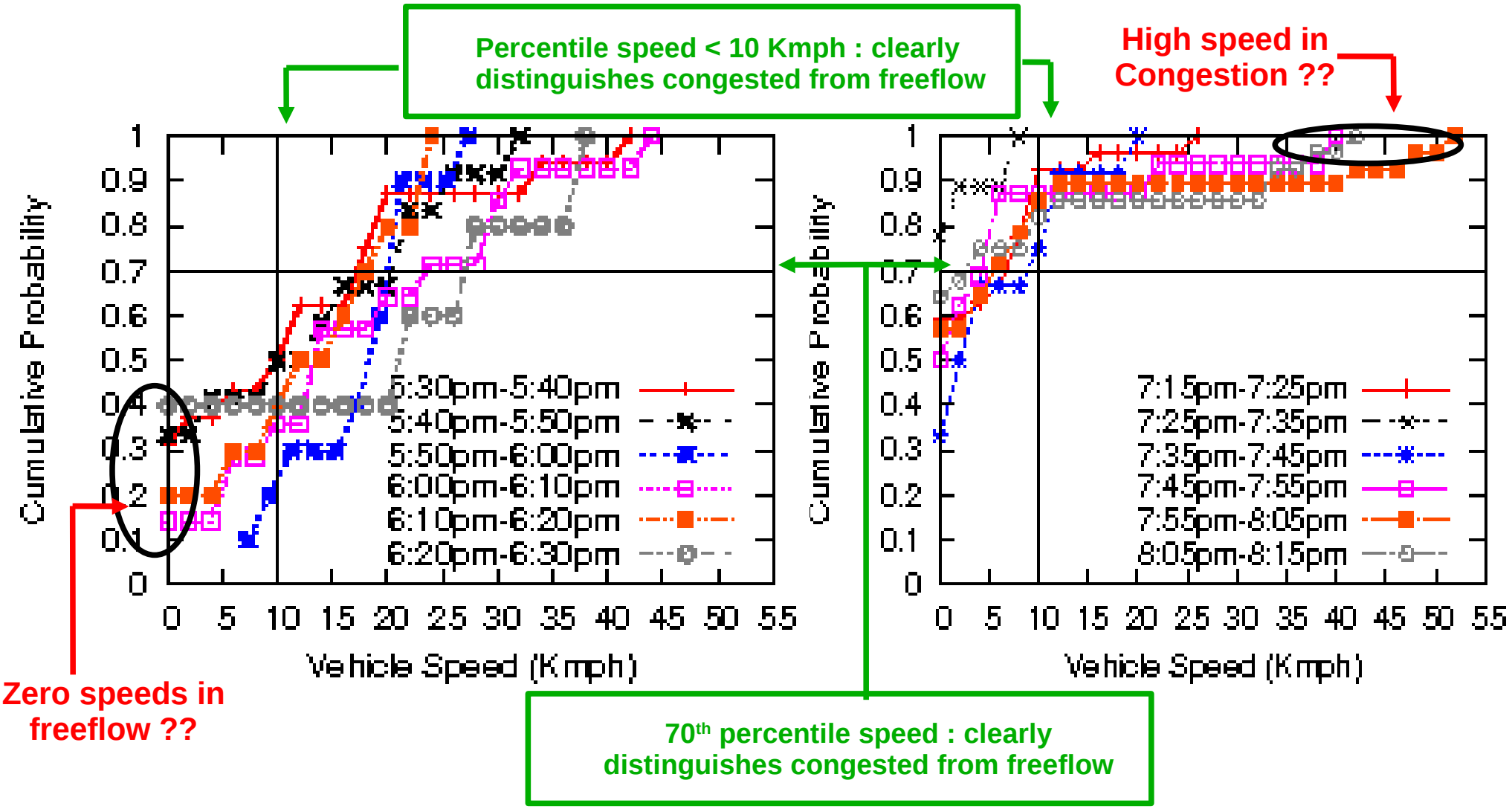
**(1) f1 = (v * f0) / (v + vs) (2) f2 = (v * f0) / (v – vs)**
**(3) vs = ((f2 – f1) * v ) / (f2 + f1)**

## Developed heuristics for

a) Recorder Synchronization
b) Honk Detection
c) Honk Matching
d) Frequency Extraction

**Extensive in-campus and on-road experiments to test speed accuracy**
**(Worst error 5 Kmph, average error 1.24 Kmph)**

# Horn-Ok-Please : Not All Speeds Are Good




18 hours road recordings to do binary traffic state classification using thresholds of metrics

a) 70th percentile speed
b) percentile speeds < 10 Kmph
c) number of honks
d) duration of honks

# Implementability Issues

- Can **computation intensive acoustic signal processing** be implemented on **embedded sensor platform**?
- Can the sensing and processing be done in **near real-time**?
- Will the **cost** be low enough?

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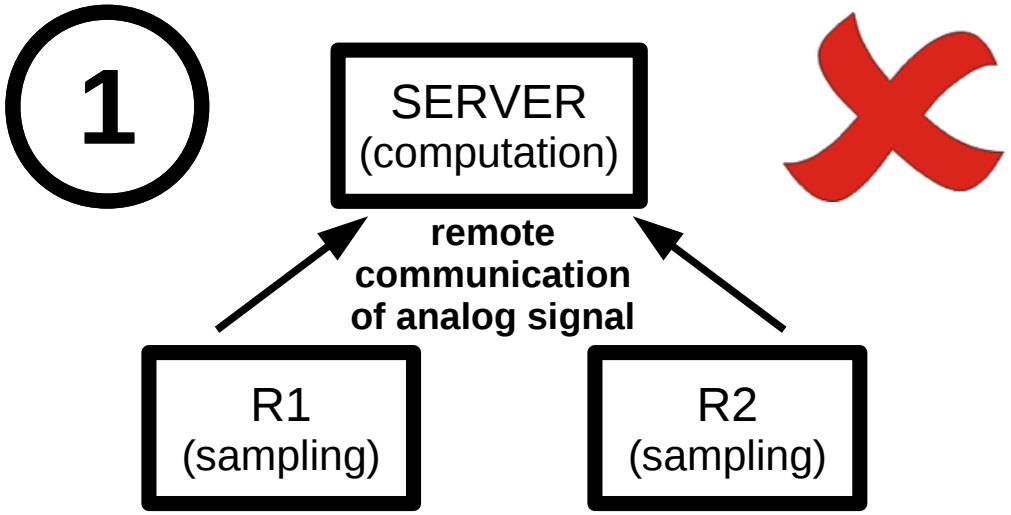
# Usability Issues

- Will the system be able to detect congestion on a **wide variety of roads**?
- Will the **traffic classification model** vary from road to road?
- What will be the **training overhead** of our system on a new road?
- Can we do without training using **unsupervized learning**?

# Design Choices



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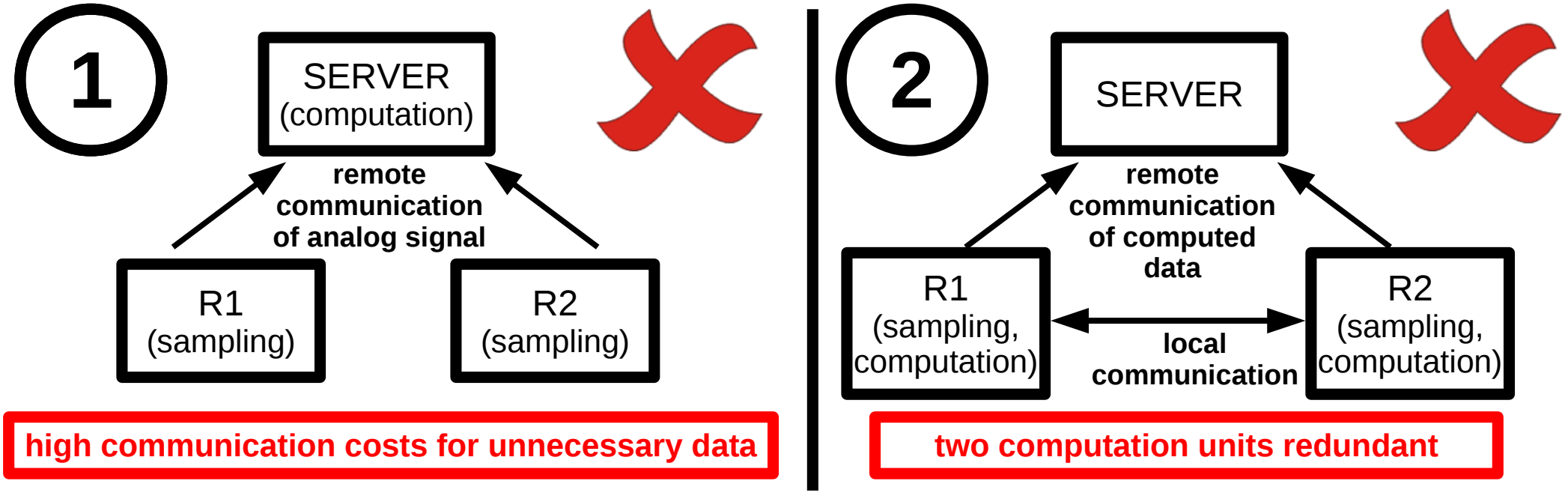
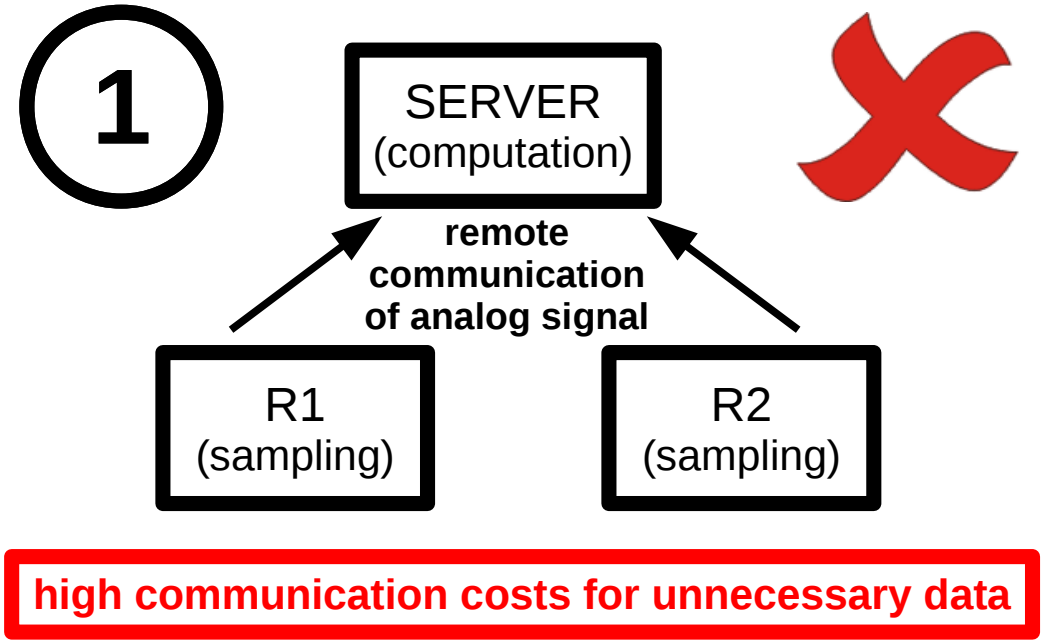
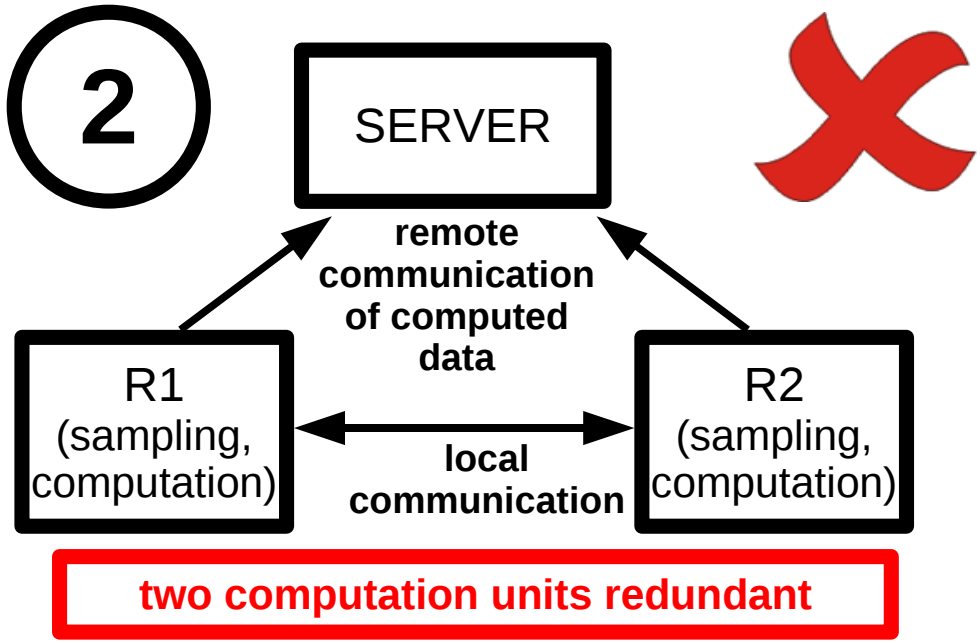


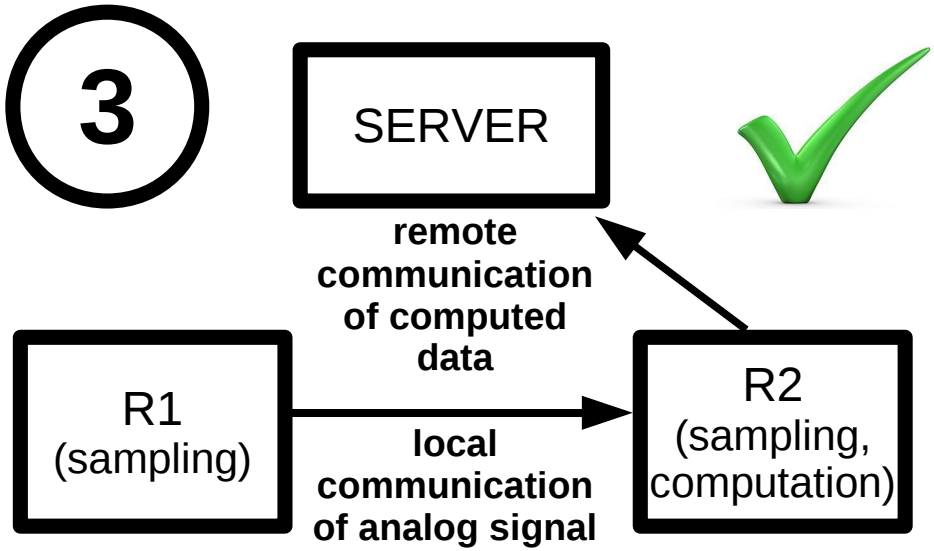
# Design Choices




high communication costs for unnecessary data

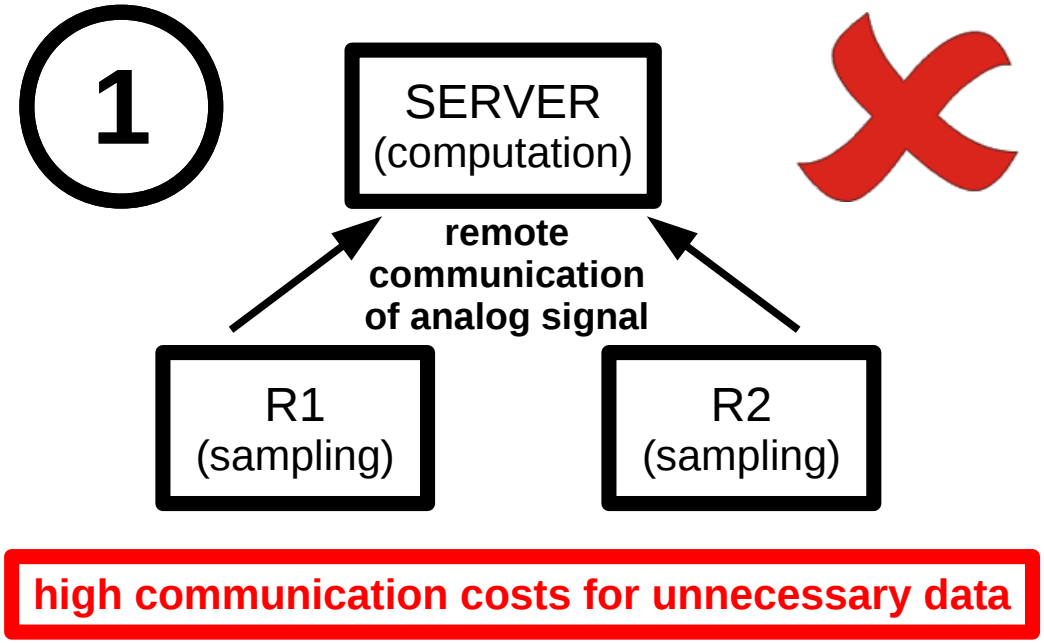



two computation units redundant




zero propagation delay, good quality local communication & high computation power at R2 needed

# Design Choices

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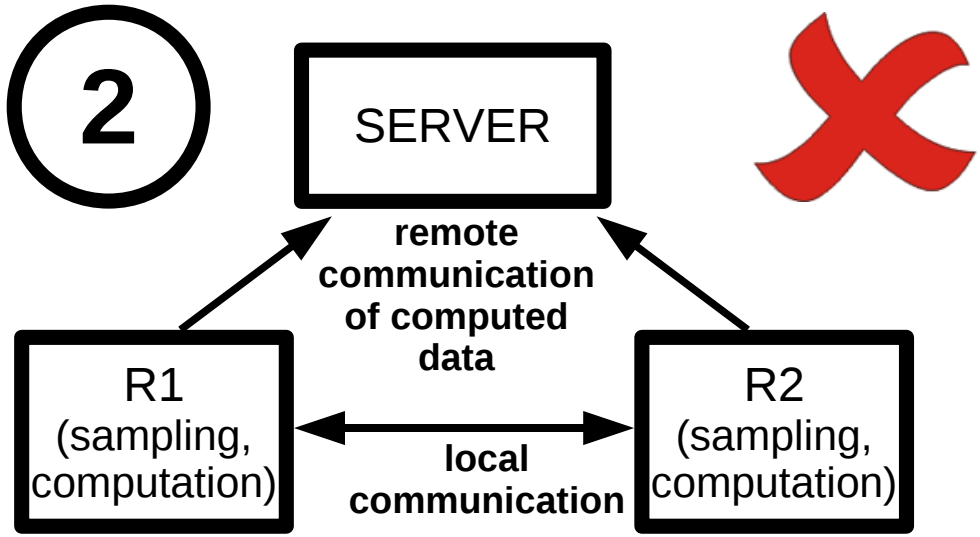
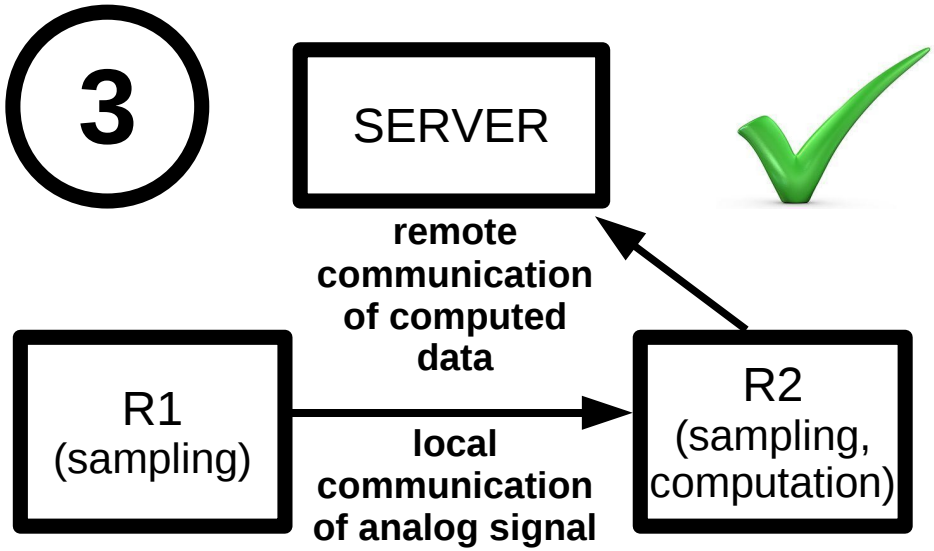



two computation units redundant

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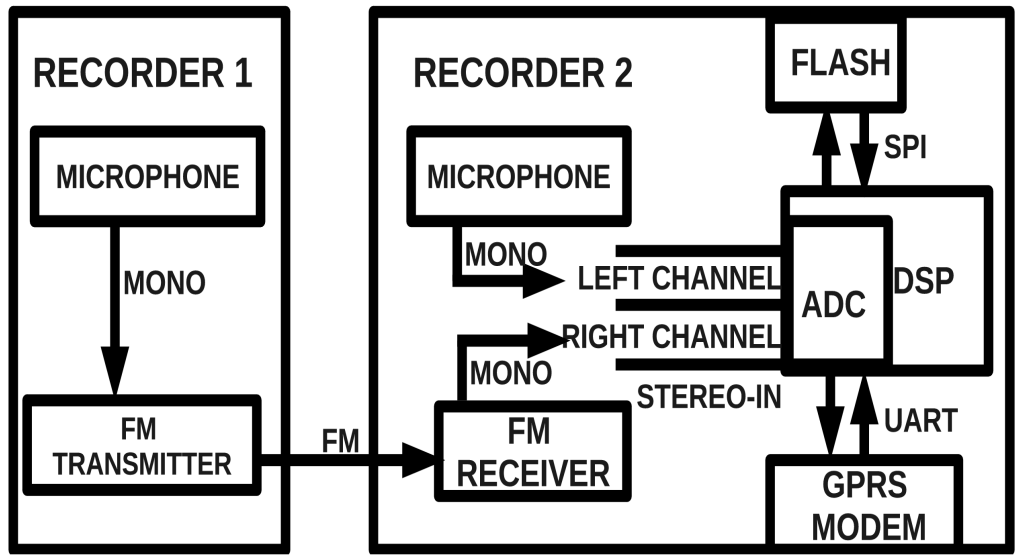


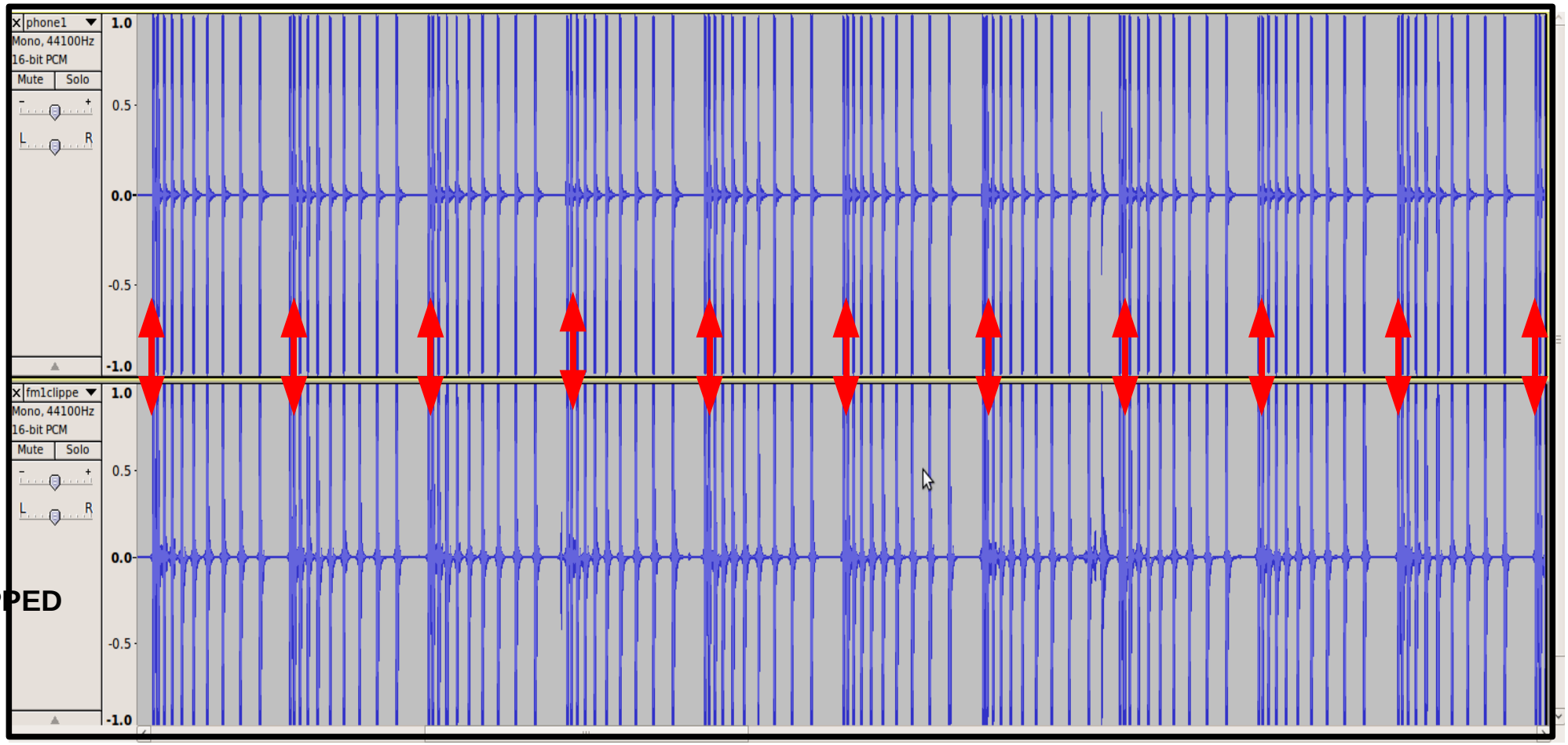

Possible hardware block diagram

# FM Propagation Delay

| Mic, fm tx | R1 | R2 laptop, fm rx | R2 laptop, fm rx | R2 laptop, fm rx | R2 laptop, fm rx | R2 laptop, fm rx | R2 laptop, fm rx | R2 laptop, fm rx | R2 laptop, fm rx | R2 laptop, fm rx | R2 laptop, fm rx | R2 laptop, fm rx |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0m | 1m | 2m | 3m | 4m | 5m | 6m | 7m | 8m | 9m ..... | 25m |

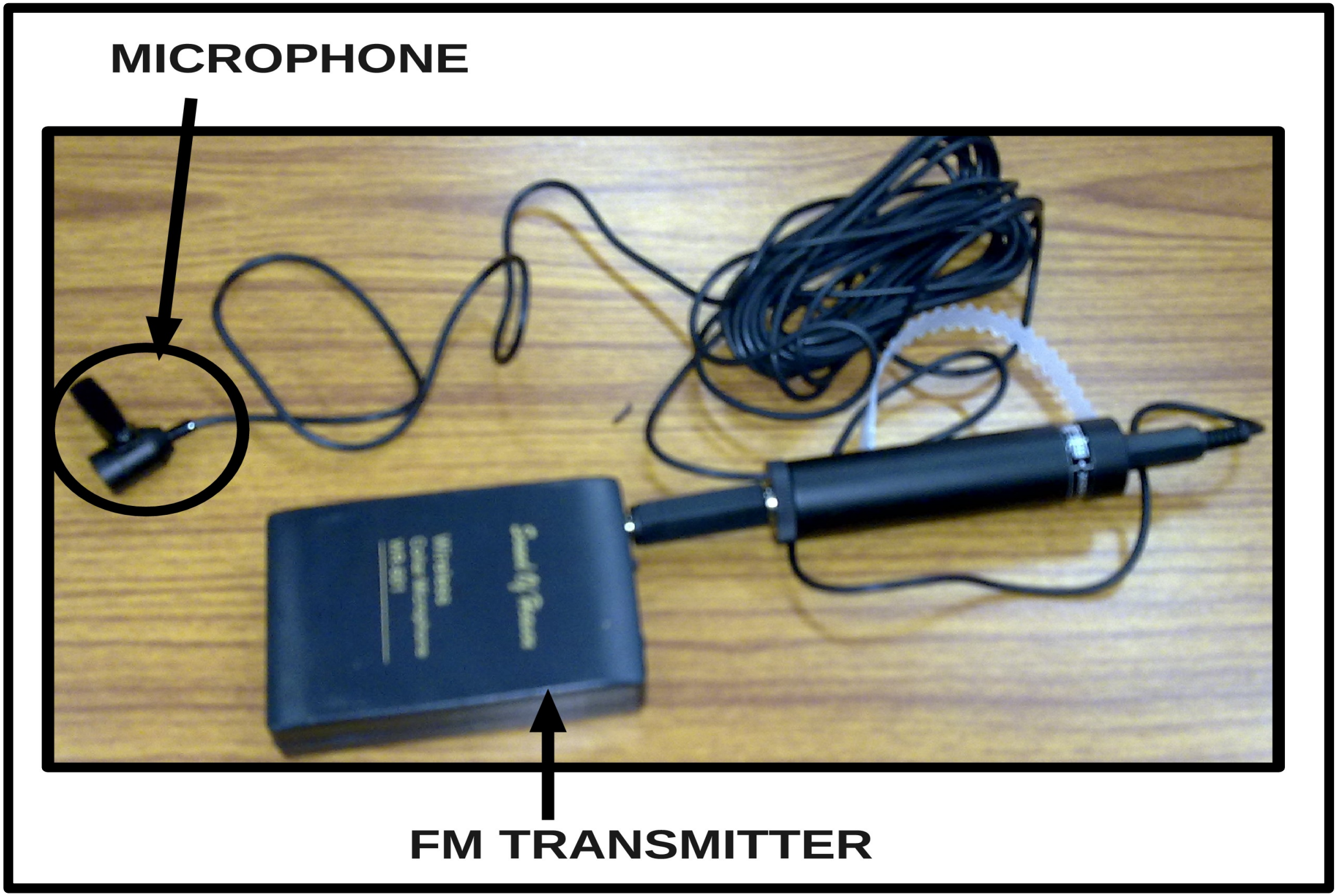
R1

R2
CLIPPED

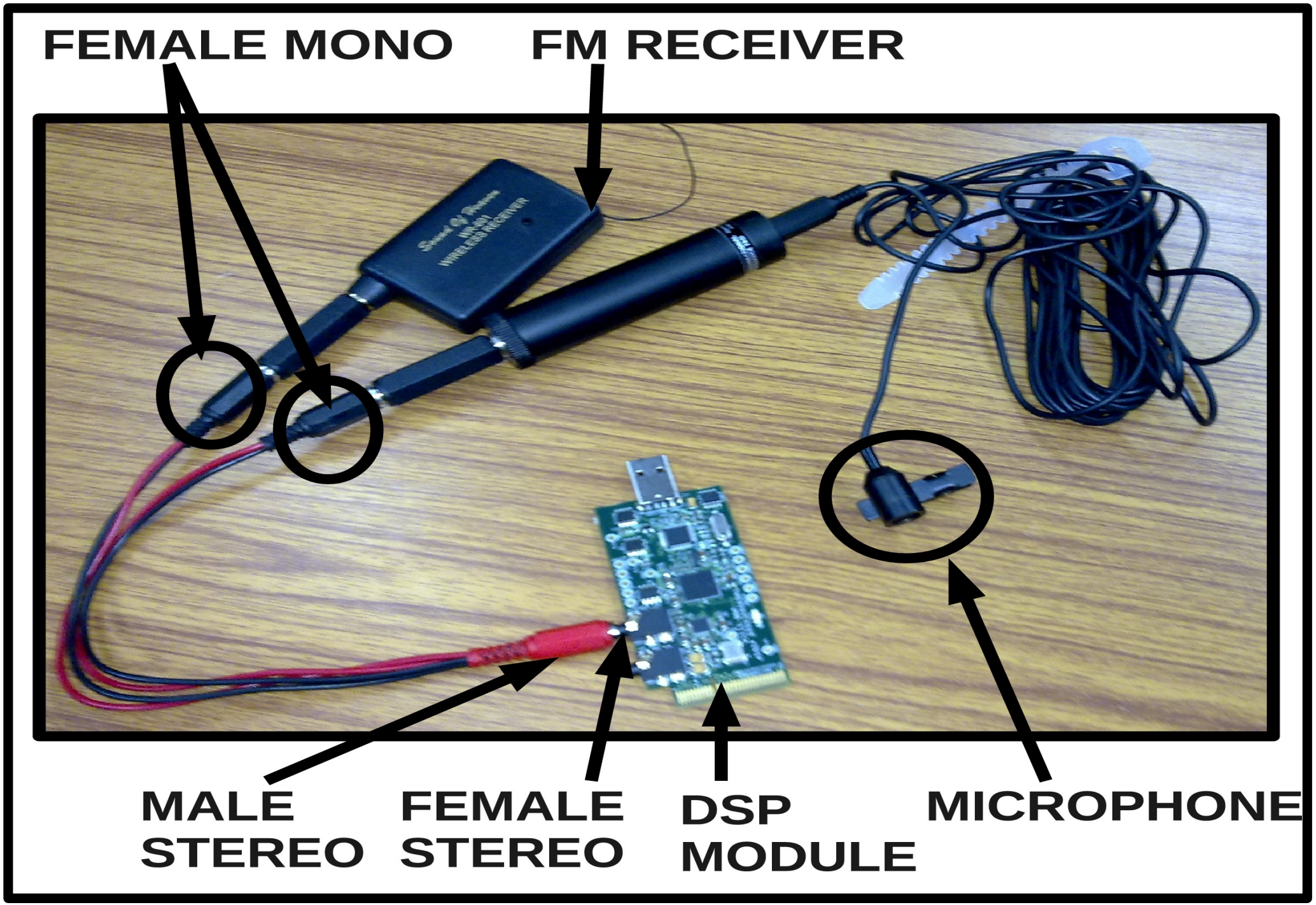



**Removing offset in one recorded pattern time synchronizes all 25 recorded patterns**

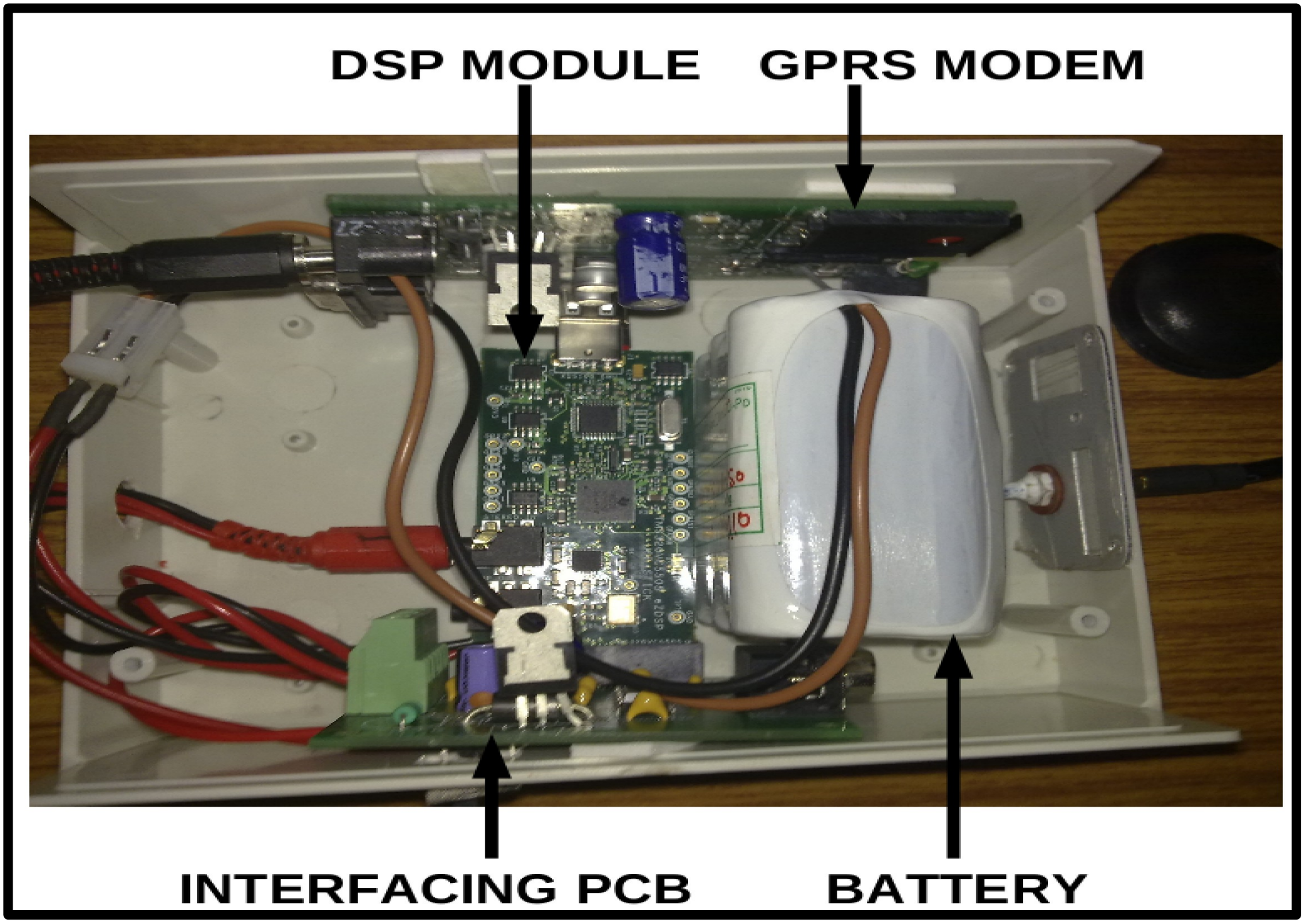
# Recorder1 (R1)



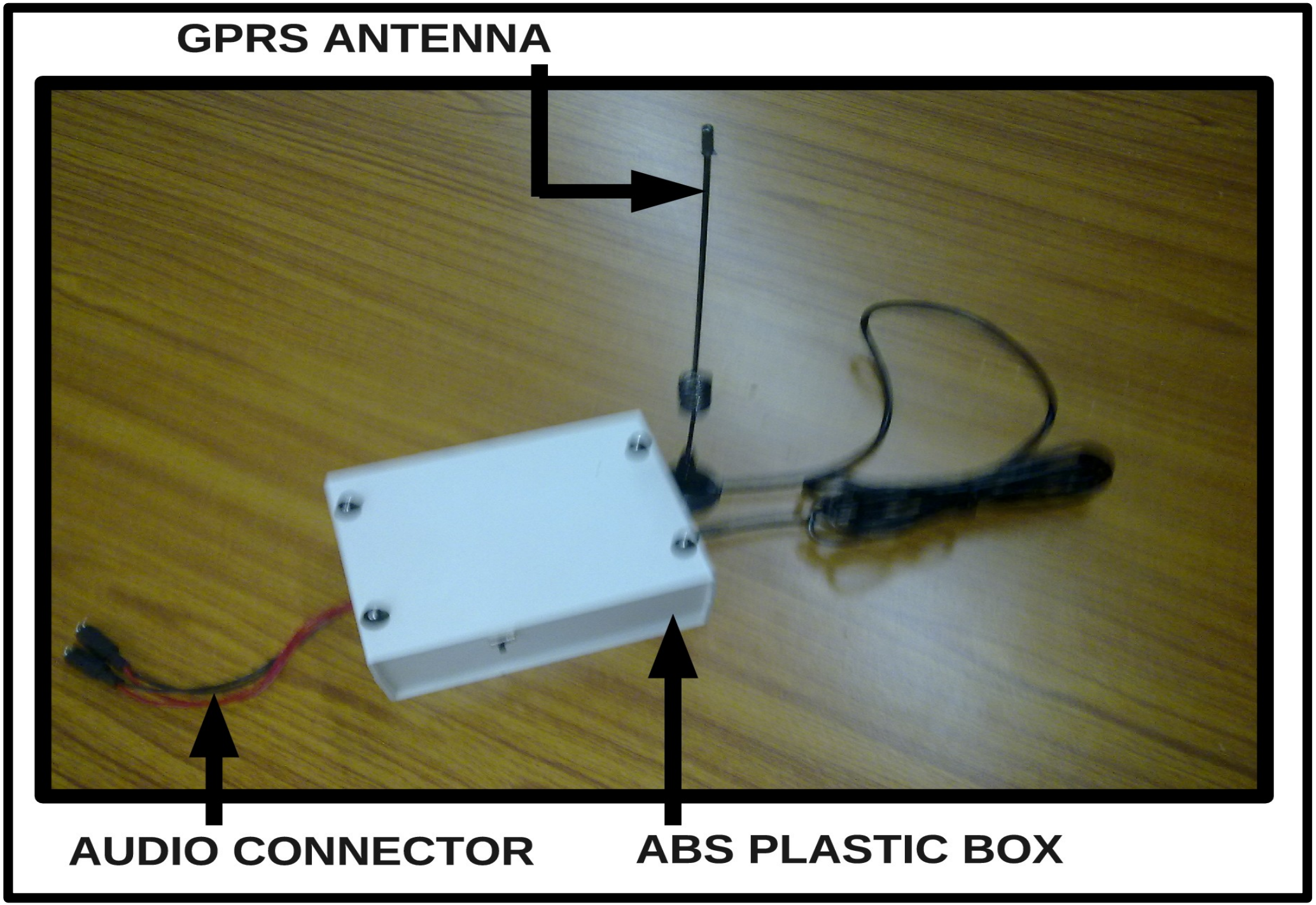
# Recorder2 (R2) – Audio Connections



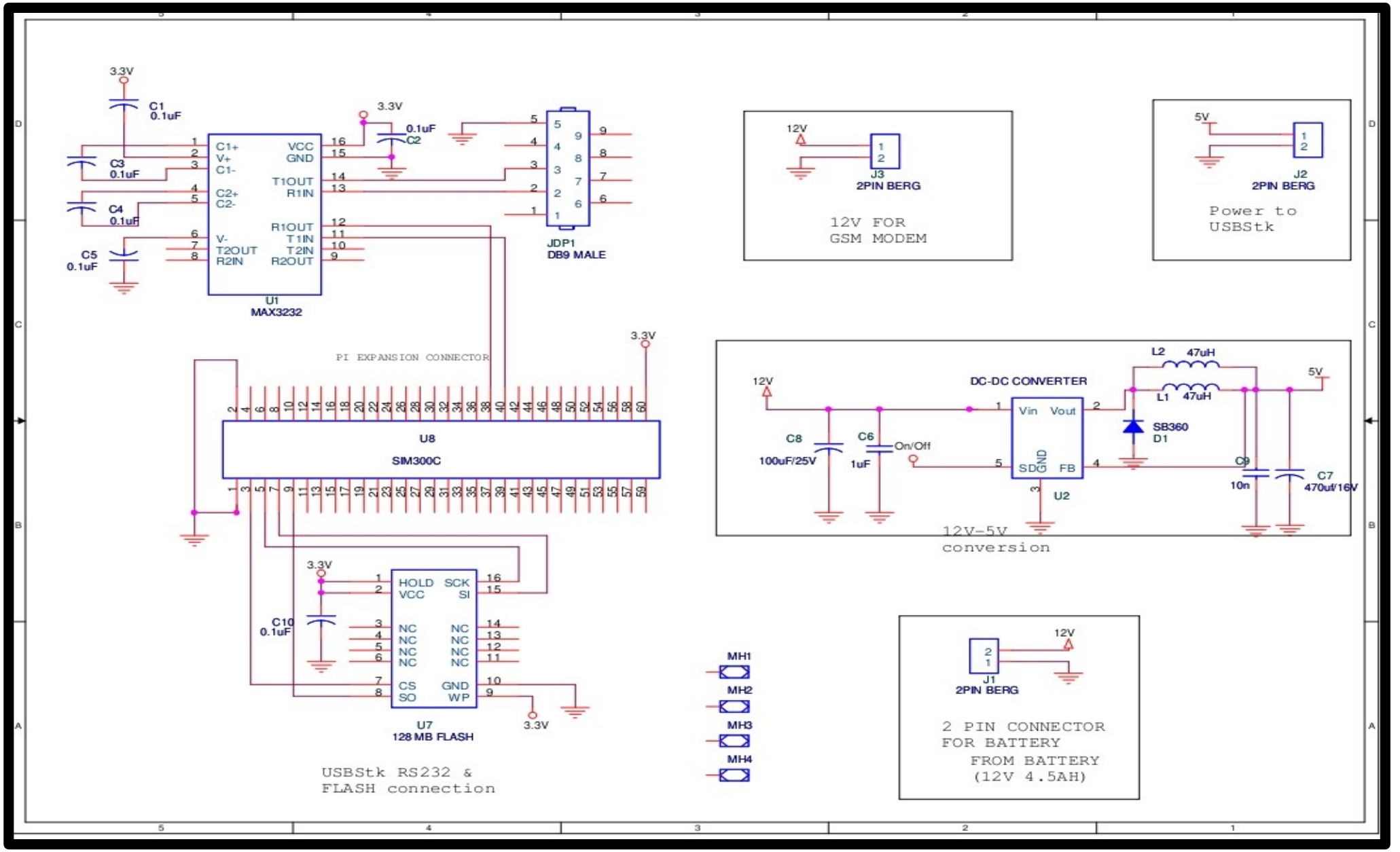
# Recorder2 (R2) – Non-audio Connections



# Recorder2 (R2) – Packaging

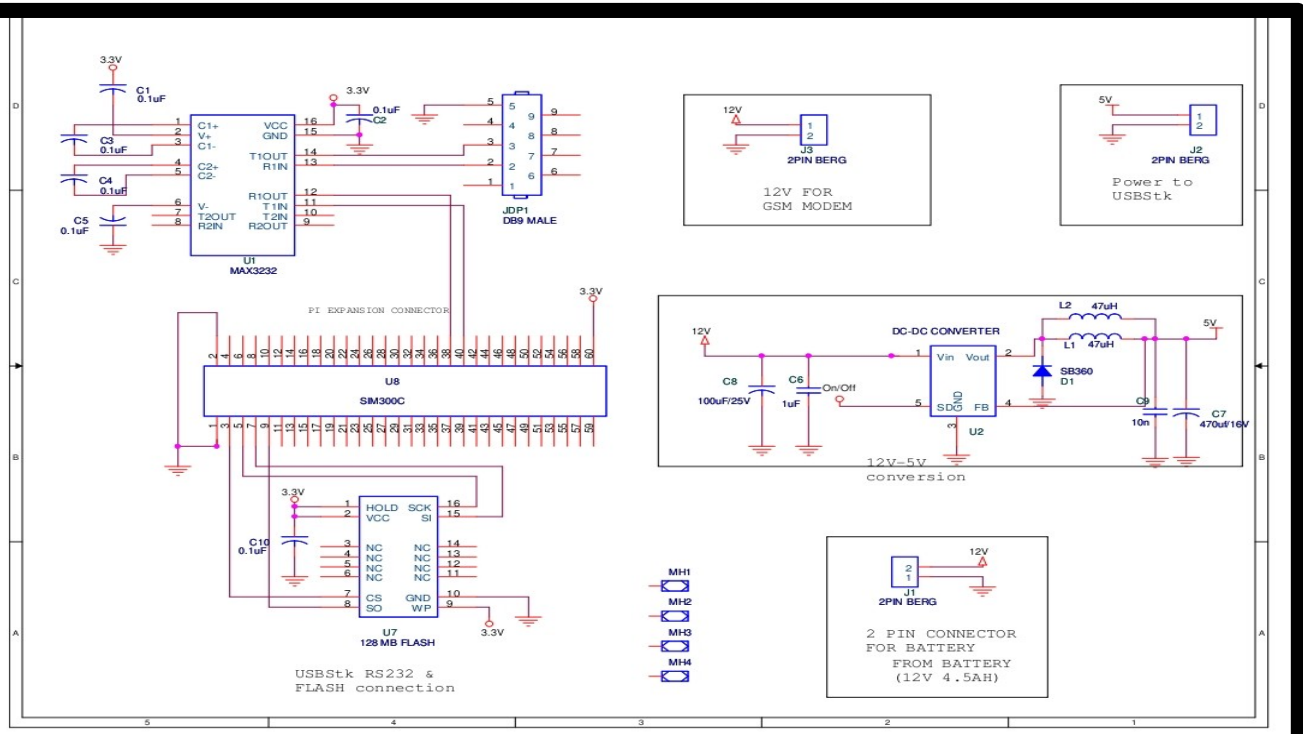


# PCB to interface DSP, flash, GPRS modem, battery

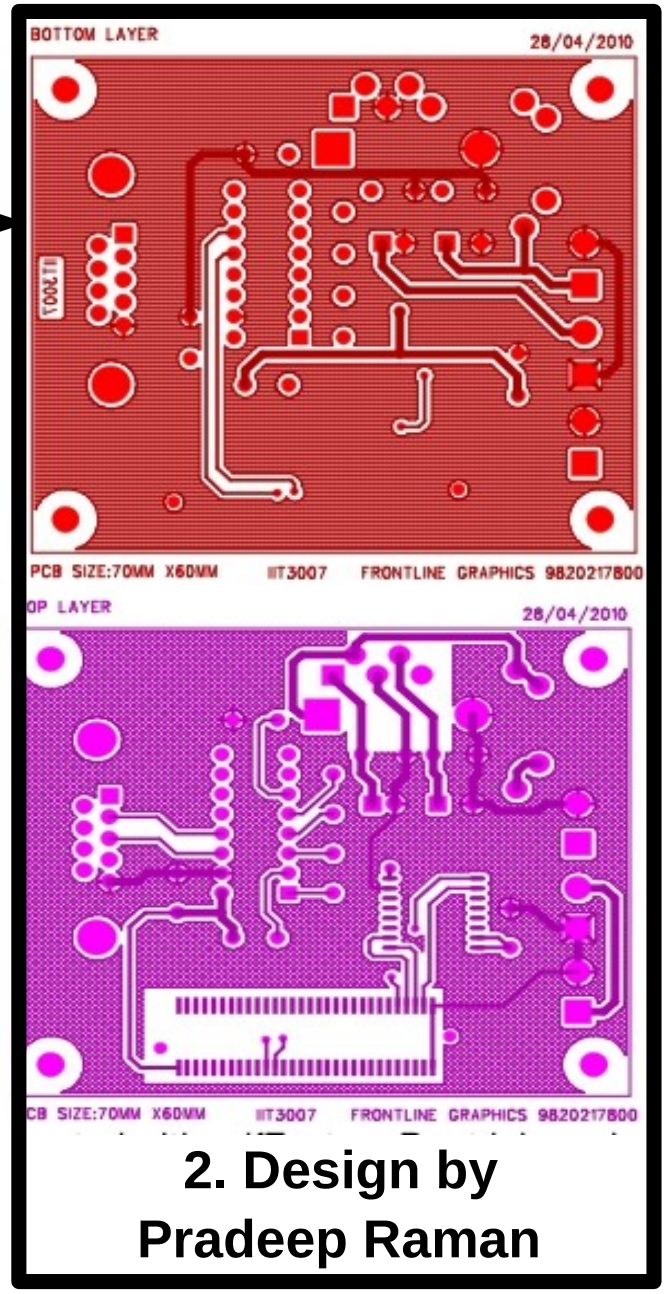



## Schematic in ORCAD

# PCB to interface DSP, flash, GPRS modem, battery

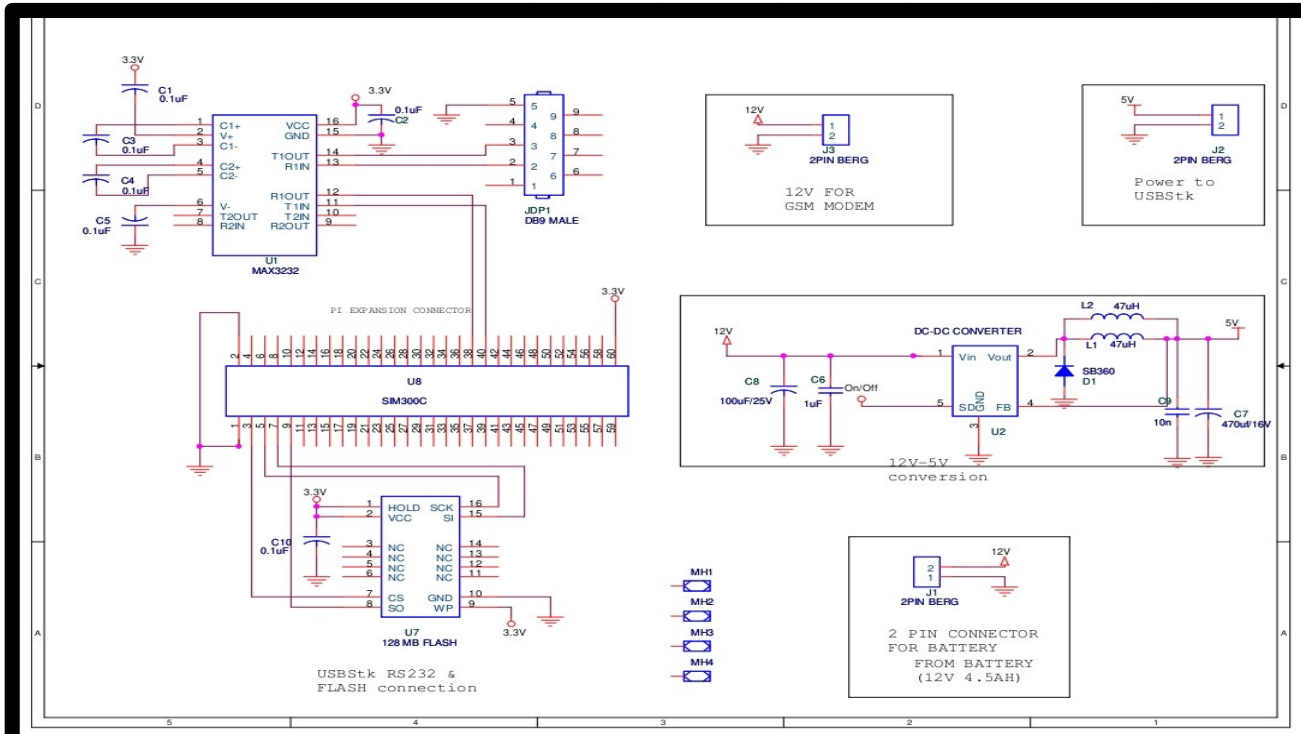



1. Schematic in ORCAD




2. Design by
Pradeep Raman

# PCB to interface DSP, flash, GPRS modem, battery

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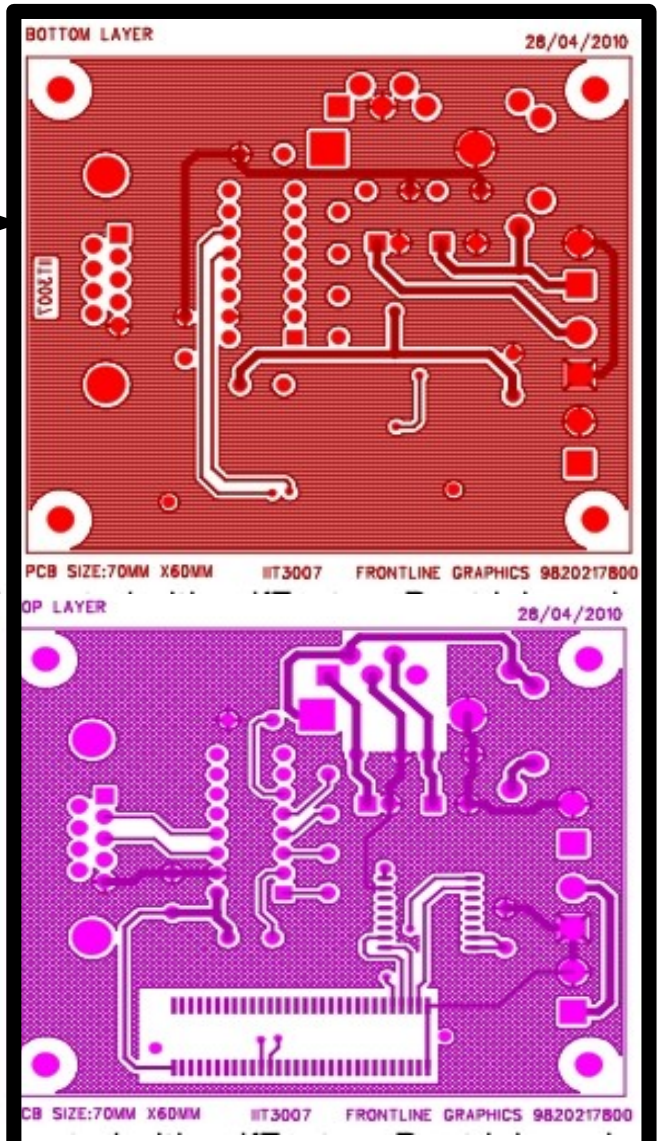


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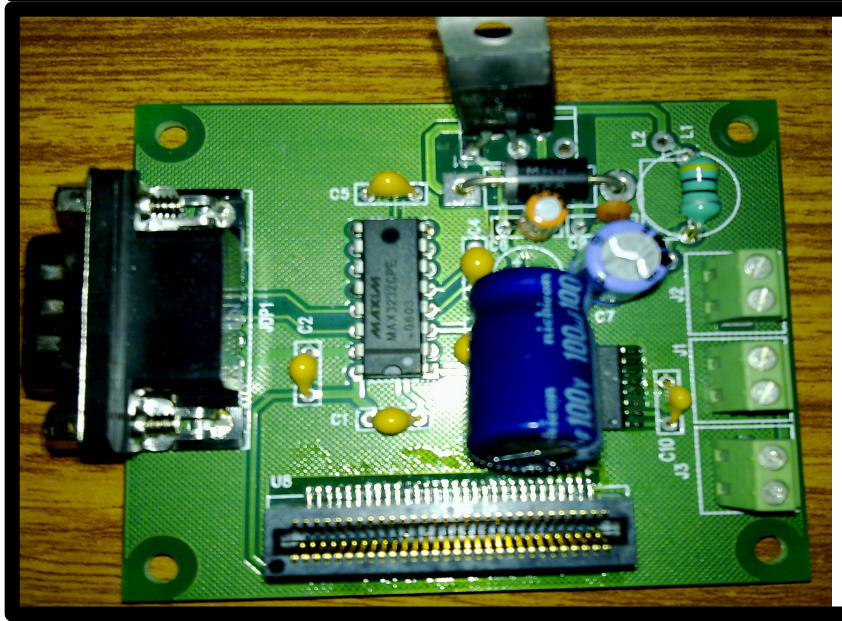


3. Final PCB after soldering components

# Hardware Components

1) **PCB design**
Pradeep Raman,
Frontline Graphics,
10, GaneshDeep C.H.S Ltd.,
Plot No. - 103, Sector – 16
**Koperkhairane,**
2754-2024, 9820217800

2) **DC-DC Converter**
Mr. Kartick
Silicon Components Pvt. Ltd.,
102-B, Rassaz Castle,
Malpa Dongri No. - 1
Near TCS compound,
Western Express Highway,
**Andheri (East)**,
2681-5500/5521, 9987273962

3) **Battery**
Jayesh Bhai,
Cymoline Batteries,
Shop No. -12,
Om Sai Byapari Mandal,
GM road, near Meghraj Hotel,
**Chembur**,
2529-2404, 2527-8848

4) **Soldering**
Rane Soldering Shop,
MMRDA Colony,
Poonamnagar,
**Jogeshwari**,
9867221859

5) **GPRS modem**
Pulraj Electronics Pvt. Ltd.
D- 28/14,
TTC, MIDC, Turbhe,
**Navi Mumbai**,
2528-0806

6) **Enclosure**
Mr. Subhash Deo,
Deo Comtech Pvt. Ltd.,
26, Sethi Industrial Estate,
Suren Road,
**Andheri (East)**,
2683-3605

7) **connectors, capacitor, resistor, inductor, IC7805, MAX3232, microphone**
**Lamington Road**

8) **Spansion 128 Mbit flash**
**SainathDigambar.Chitte@Avnet.com**

9) **TI 5505 ezdsp USB stick**
**ratishr@farnell.com**
**vineshpulse@farnell.com**

10) **FM transmitter receiver**
**http://shopping.rediff.com/product/Wireless-Clip-On-Mini-Microphone/975380**

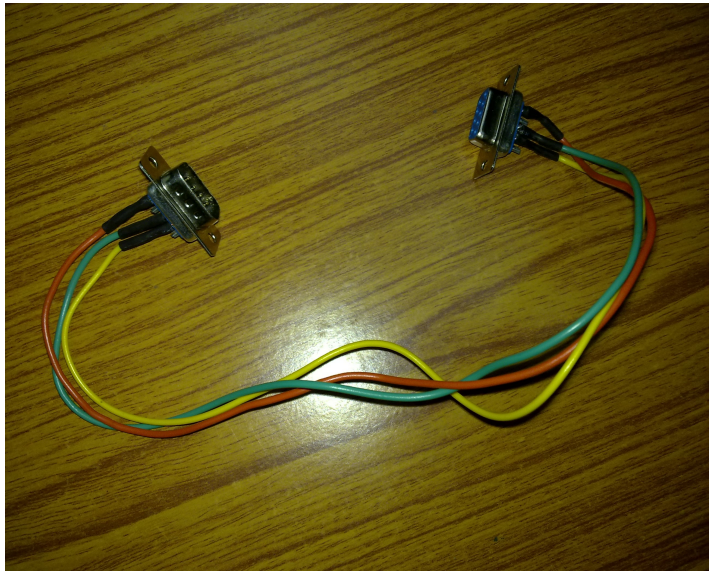
11) **USB stick expansion connector**
**www.samtec.com/ProductInformation/TechnicalSpecifications/Overview.aspx?series=MEC1**

12) **Clamp, lock, key, suitcase chain**
Shop outside IITB main gate

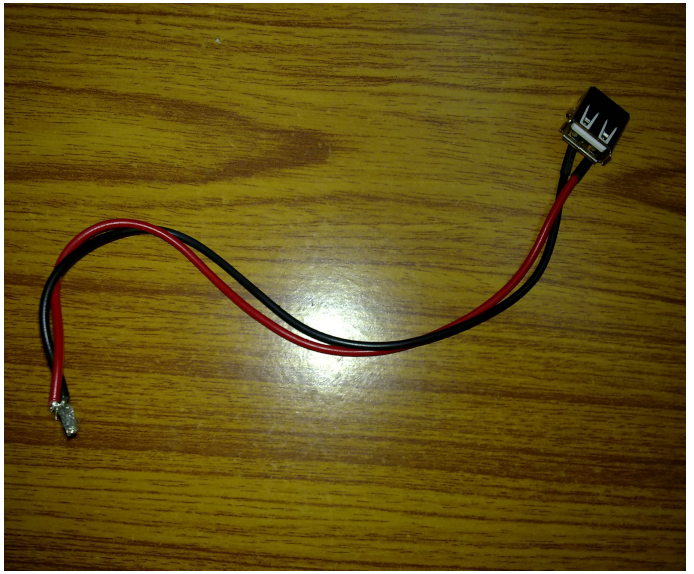

## Acknowledgement:

**Pankaj Siriah**
**9323709950**

# Connectors

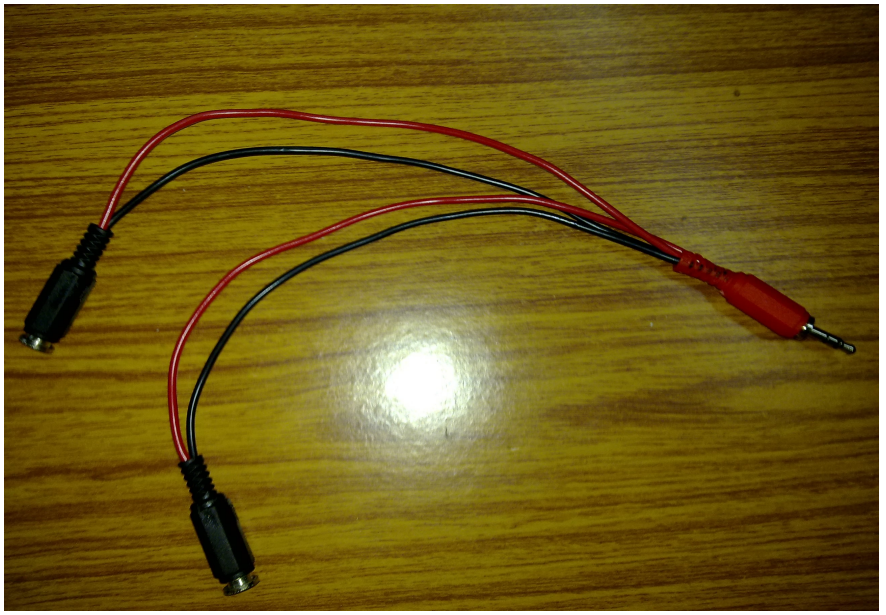


serial connector from interfacing PCB to GPRS modem (6 solder points)

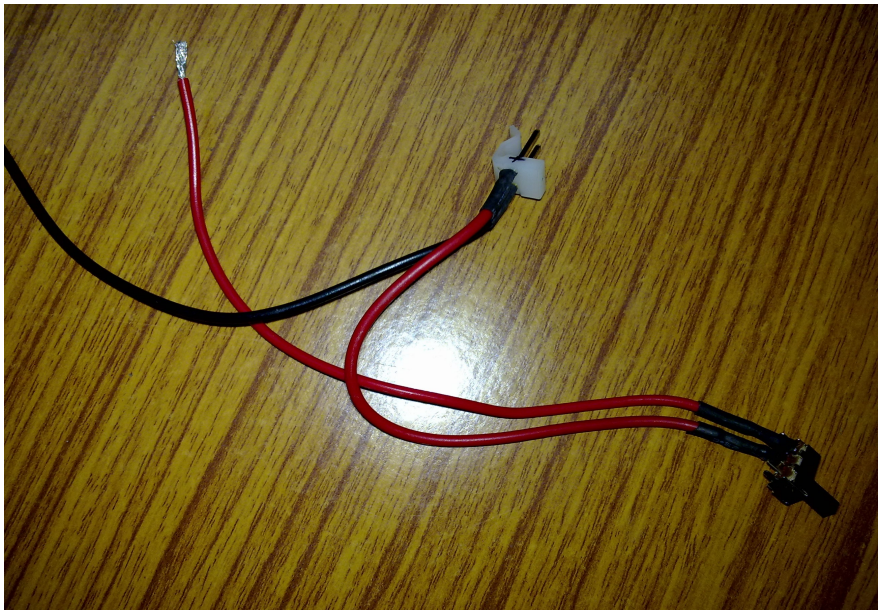


power to ezdsp from interfacing PCB (2 solder points)

power to GPRS modem from interfacing PCB (2 solder points)



audio connector, two mono inputs, one stereo output (8 solder points)

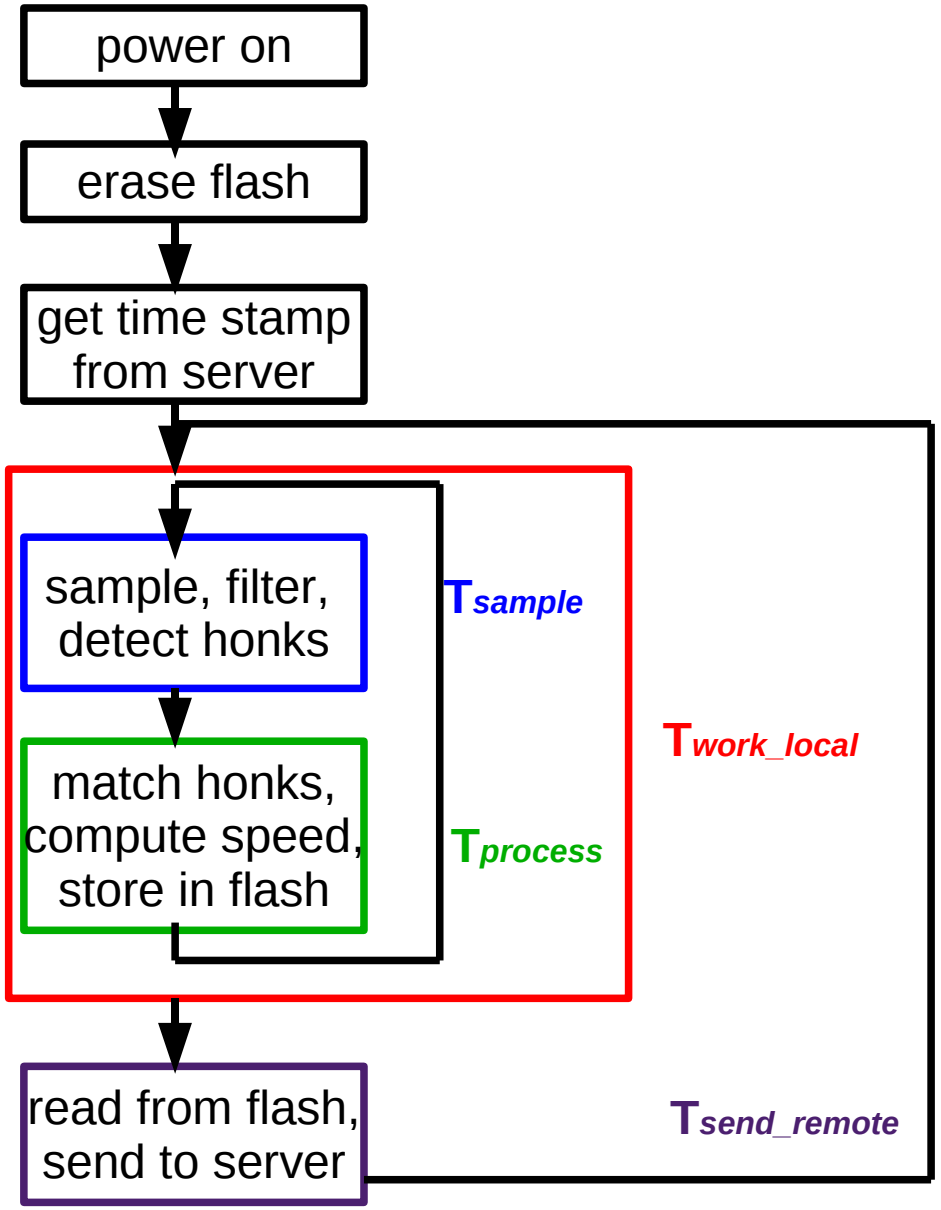


power from battery to interfacing PCB through switch (4 solder points)

**Total 22 solder points per prototype**

# Software

## Flow-Chart




## Choice of parameters

**$T_{sample}$ (resource constraint)**

- 128 point FFT needs 128 samples
- Each sample 2 bytes
- 125 windows of 128 samples at 16 Khz
- Each window has 2 byte timestamp (10 bits millisecs, 6 bits secs)
- (((128 x 2) + 2) x 125) bits/sec = 32 KB/sec to be stored during honk detection in worst case
- 64 KB/sec for two channels
- 320 KB RAM, 256 KB after storing stack, code, temporary variables
- 256KB/64KB/sec = 4 secs is $T_{sample}$

**$T_{process}$, $T_{send\_remote}$ (repeated experiments to ascertain worst case delay)**

- experiments with flash write time
- 5 usecs is chosen as $T_{send\_remote}$
- Experiments with flash read and GPRS connection establishment time
- 50 secs is chosen as $T_{process}$,

**$T_{work\_local}$ (application requirement)**

- Want updates at server every alternate minute
- 60 secs is chosen as $T_{work\_local}$

# Cost Per Prototype

| Item | Unit Price ($) | Quantity | Cost ($) |
|---|---|---|---|
| DSP module | 50 | 1 | 50 |
| GPRS modem | 50 | 1 | 50 |
| FM tx-rx | 15 | 1 | 15 |
| Microphone | 5 | 2 | 10 |
| Interfacing PCB | 5 | 1 | 5 |
| Battery | 20 | 1 | 20 |
| Enclosure | 5 | 1 | 5 |
| Flash | 3 | 1 | 3 |
| Connectors | 0.4 | 5 | 2 |
| Total | | | 160 |

| 10 bits | 6 bits | 6 bits | 5 bits | 5 bits |
|---|---|---|---|---|
| millisecond (0-1023) | second (0-59) | minute (0-59) | hour (0-23) | day (1-31) |

4 bytes (timestamp) + 1 byte (number of honks on left channel) + 2 bytes (duration of honks on left channel) + 1 byte (number of honks on right channel) + 2 bytes (duration of honks on right channel) + 1 byte (number of speeds) + x bytes (actual speed values)

**= [ (11 + x ) * 8 bytes ] per minute**

**Vodafone GPRS SIM cards have Rs. 99 monthly rental and 10p charge per 10 KB of data**

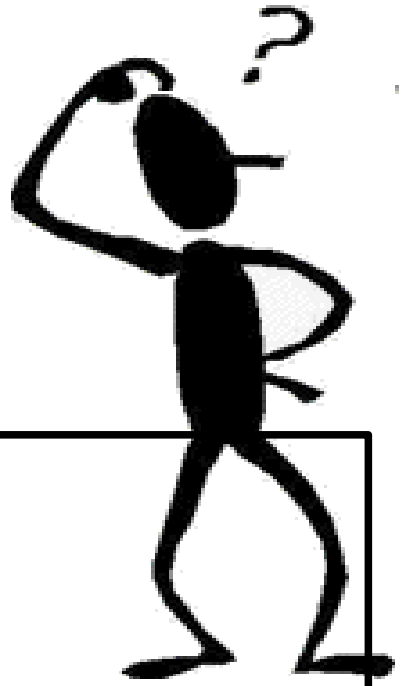
# Getting Stuck

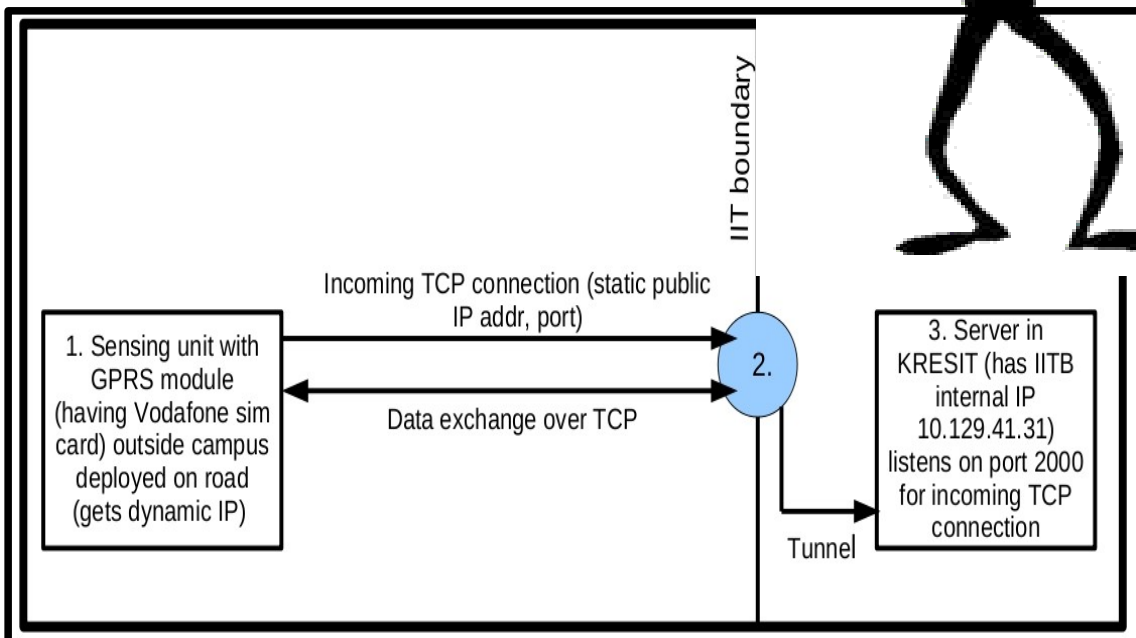
Problem : GPRS modem not working
Solution : shorting RTS and CTS pins
Pramod Mhaske

Problem : flash storing garbage value
Solution : setting flash to all 1's before writing

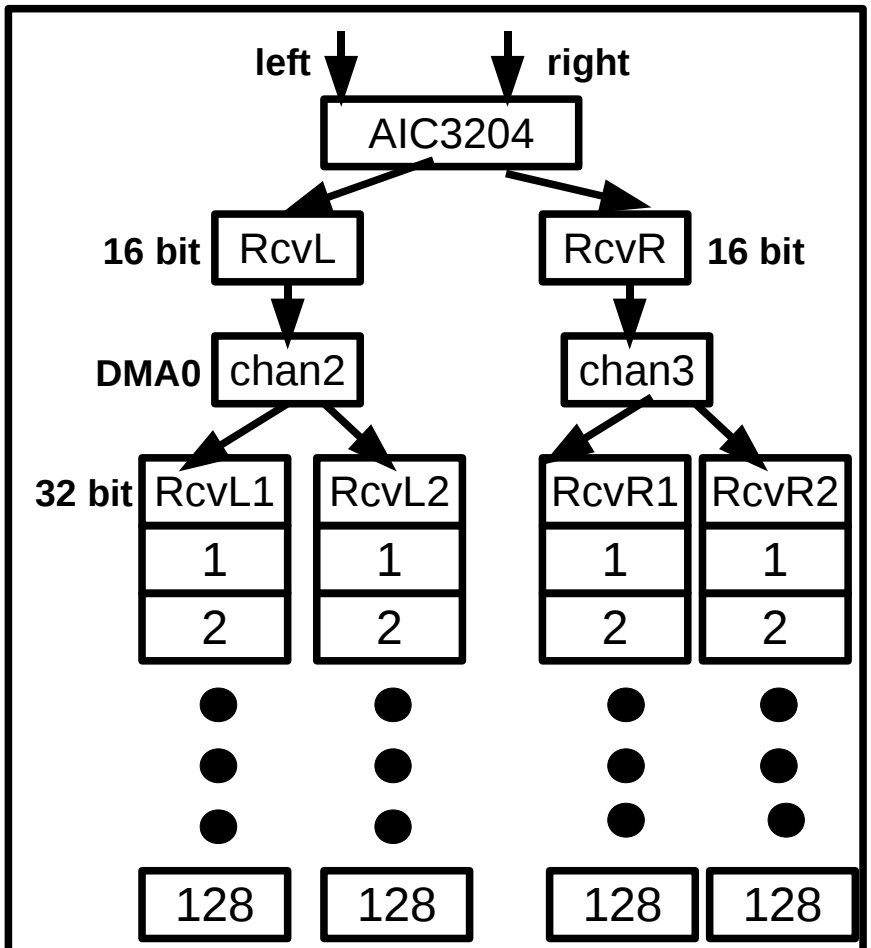
Problem : printf removed, code stops running
Solution : introduce delays

Problem : DC-DC converter having fluctuating output voltage
Solution : use IC 7805 instead
Pankaj Siriah



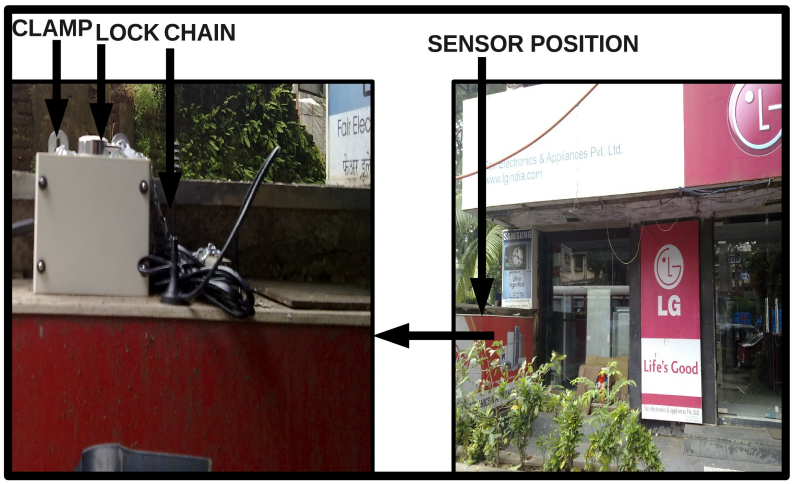



Problem : prototype on road cannot talk to lab machine
Solution : tunneling through public IP
Abhay Karandikar, Ajit Jena @ CC




Problem : samples missed while processing
Solution : ping-pong buffers
code.google.com/c5505ezdsp

# Deployment

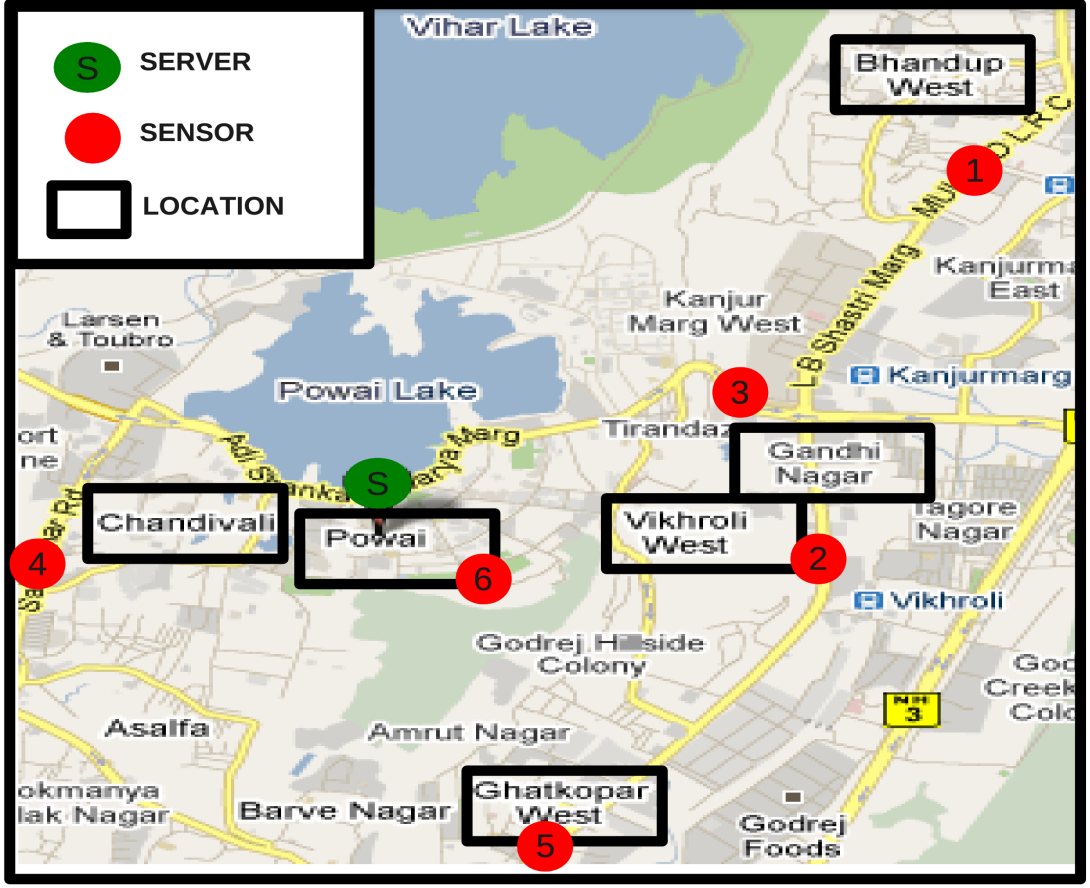



Sample Deployment at Bhandup

## Choice of locations

- Not very near to traffic signal
- Not very far from traffic signal
- Not after traffic signal
  150-200m before traffic signal
- Near important road junctions or railway stations to ensure congestion in peak hours
- 5-6Km from IIT to reduce trip time from lab to each location

http://www.cse.iitb.ac.in/~riju/rss-videos/

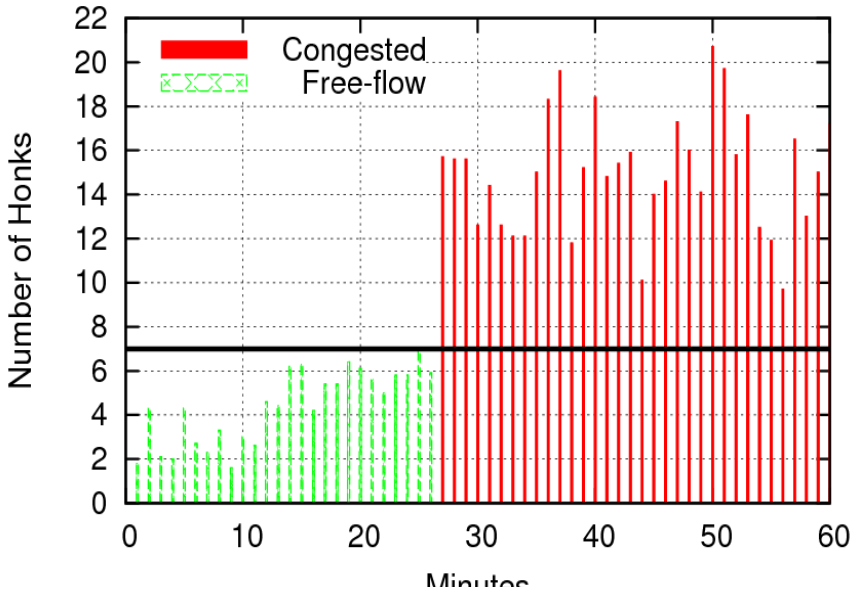


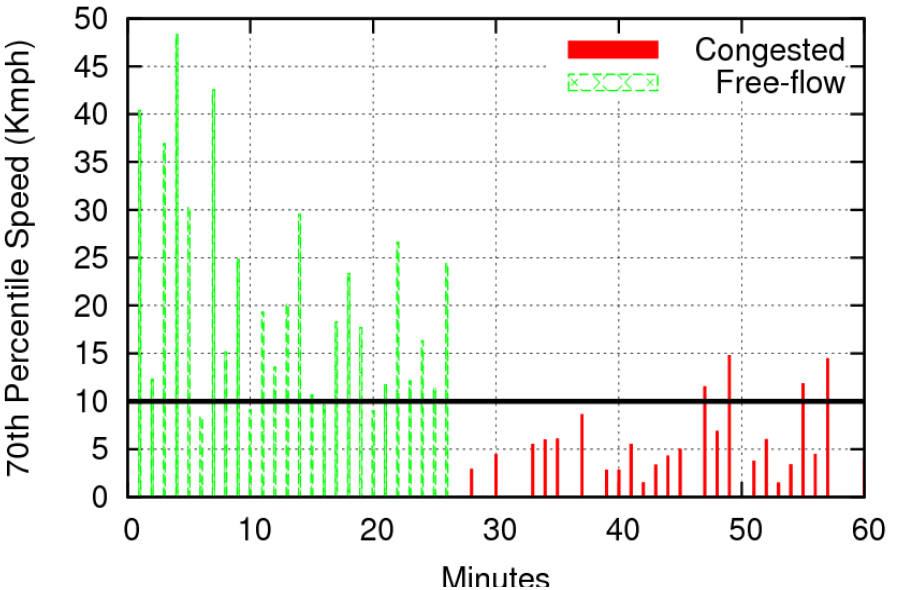

Sensor Deployment Locations in Googlemap

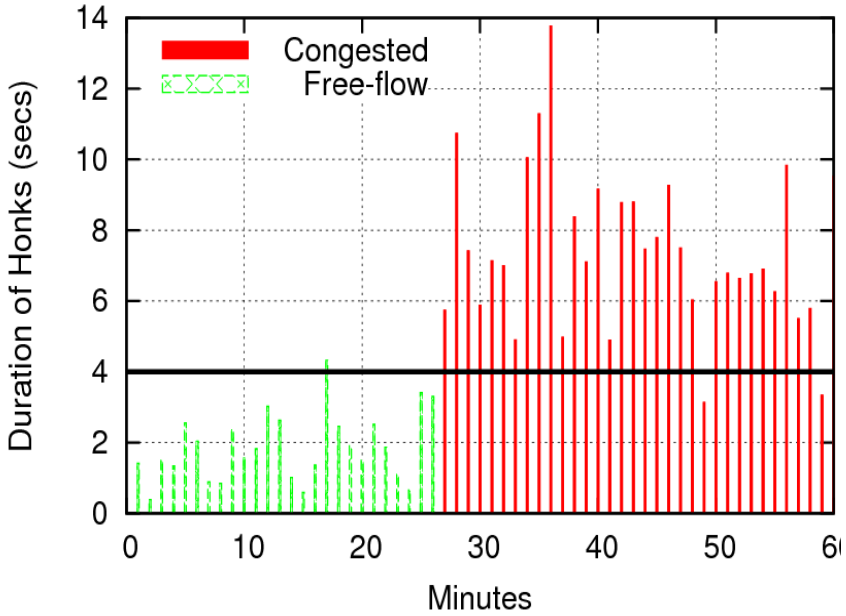
| No. | Location | Road bi-directional | Road width (each way) | Vehicle type |
|---|---|---|---|---|
| 1 | Bhandup | Yes | 10m | All |
| 2 | Vikhroli | Yes | 10m | All |
| 3 | Gandhinagar | Yes | 25m | All |
| 4 | Chandivali | Yes | 15m | All |
| 5 | Ghatkopar | Yes | 10m | All |
| 6 | Powai (Hiranandani) | Yes | 8m | Light |

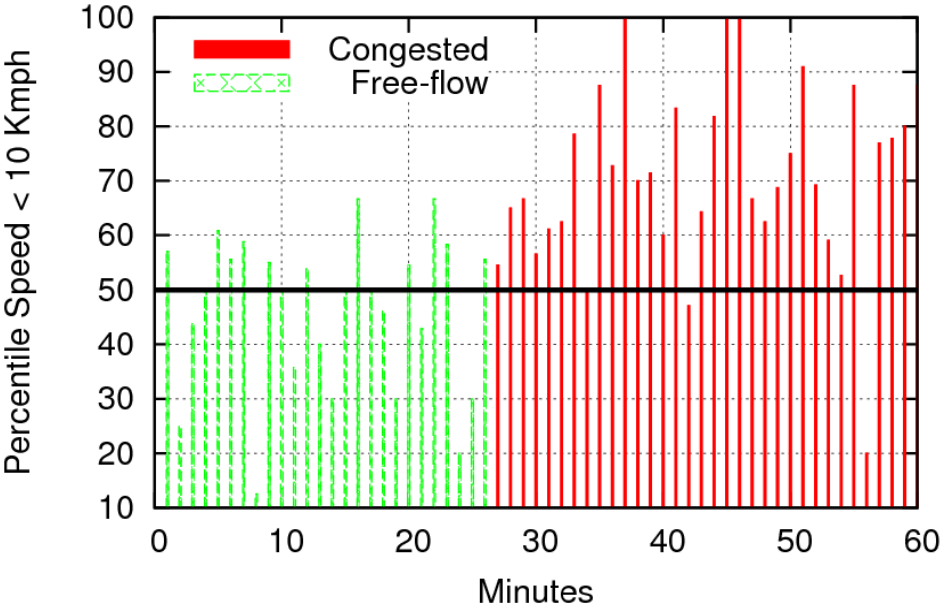
Deployment Location Details

# Gandhinagar



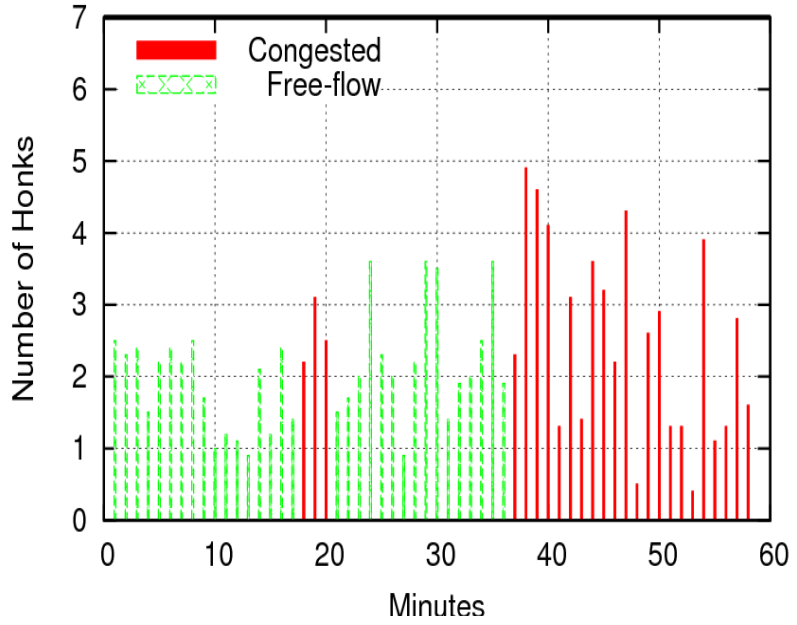



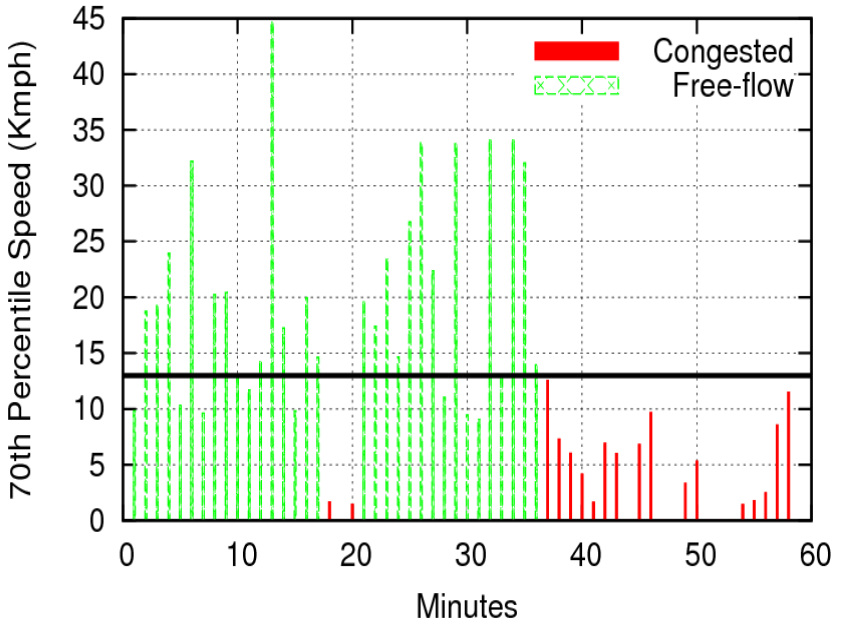



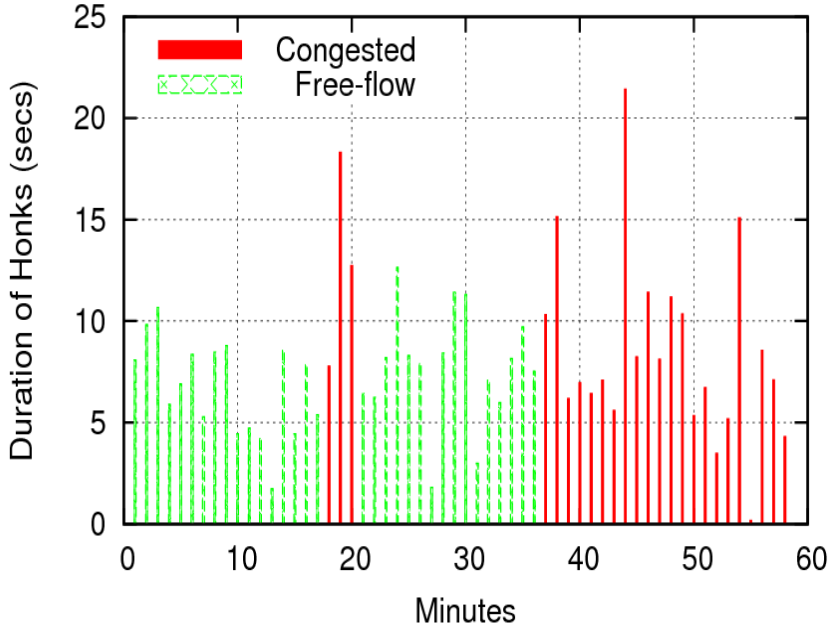



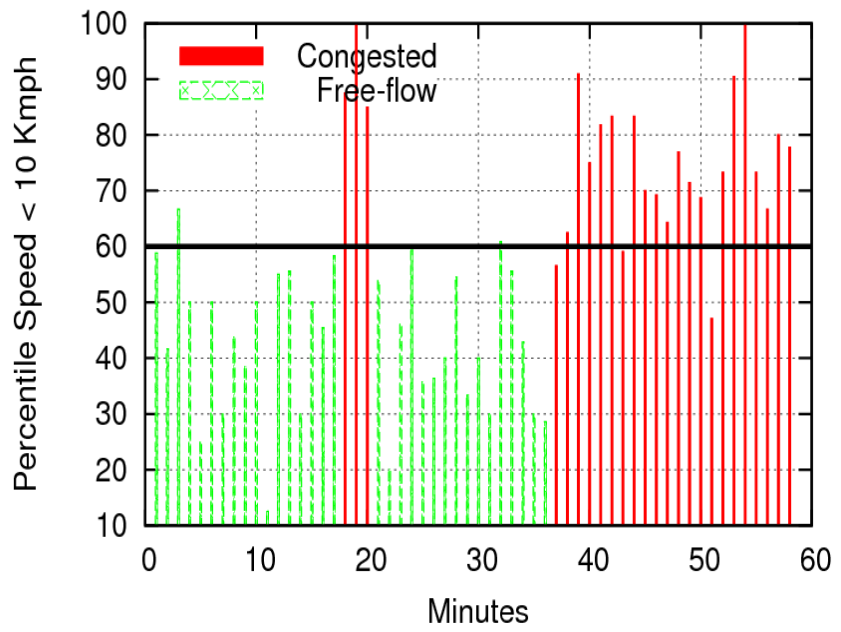

**25 m wide road causes many times increase in vehicle number in congestion from free-flow, increasing honk-based metric values, which suffice in congestion detection.**
**Speed-based metrics, more complex to compute, are unnecessary.**

# Vikhroli



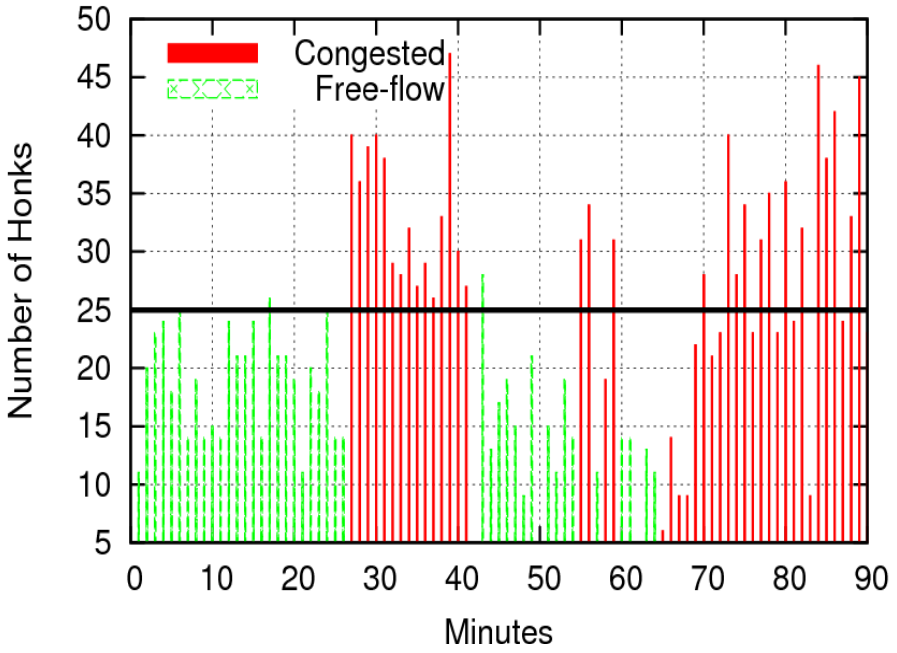



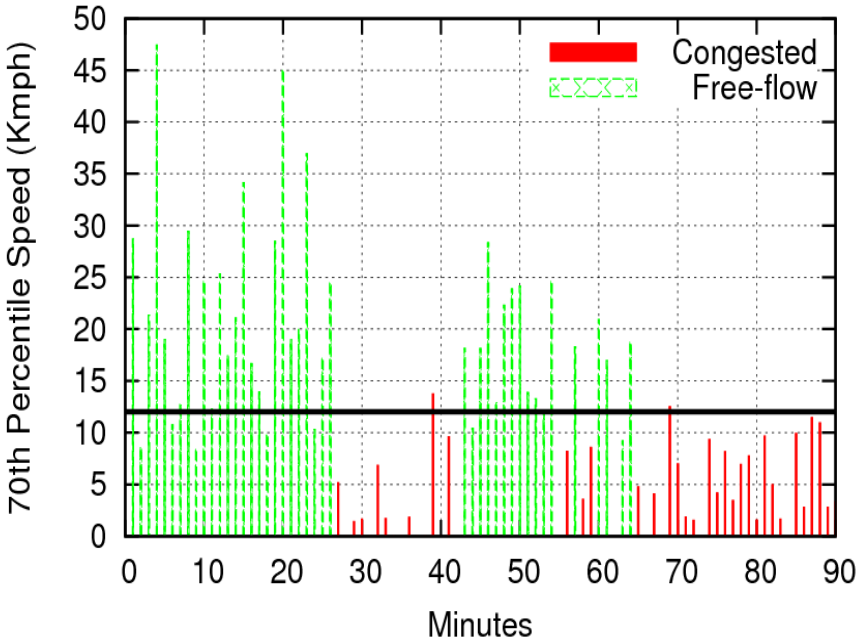



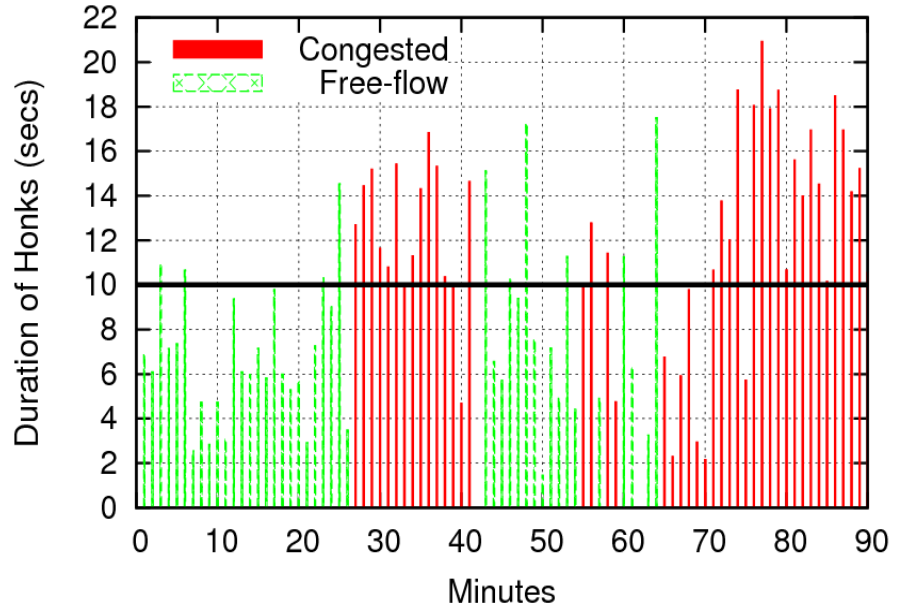



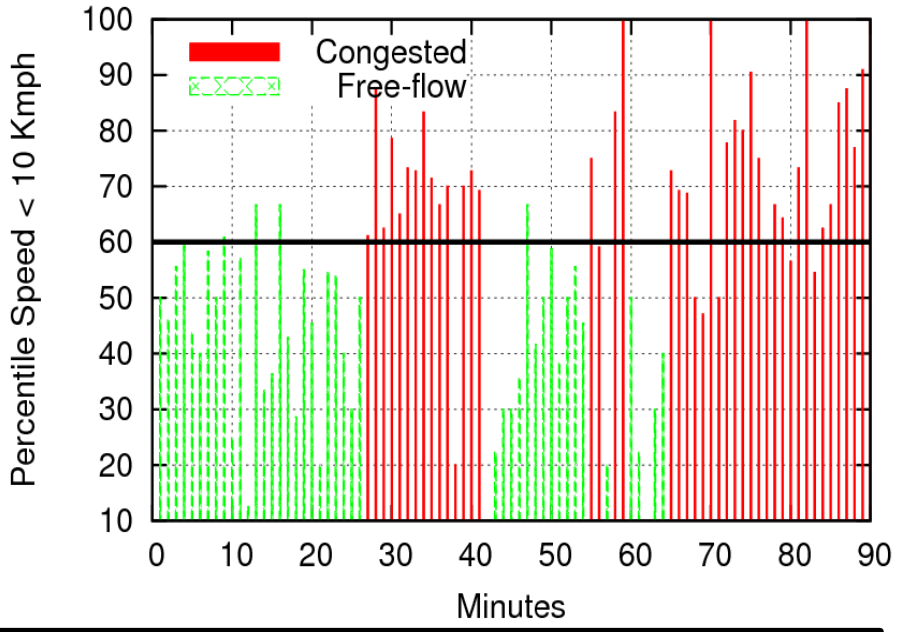

**Cut in divider immediately in front of deployment causes most vehicles to blow honks, even in free-flow, to alert the road crossing pedestrians. Honk-based metrics are unduly inflated.**
**Only speed based metrics should be used.**

# Bhandup




**All metrics show the difference between traffic states. But roads being narrow, honks from opposite direction get recorded, giving inflated values of honk-based metrics.**
**Thus speed-based metrics should be given more weightage.**

# Automation: Machine Learning Tools

- **Separate training set** for each road -- 90 instances for Bhandup, 58 instances for Vikhroli, 60 instances for Gandhinagar, Chandivali, Ghatkopar, Powai (Hiranandani)
- **6 attributes for each instance** – 4 honk-based metrics and 2 speed-based metrics
- **1 class label for each instance**, congested or free-flow, based on manual observation

## Classification Models

| *Bhandup (Accuracy 93.2%)* | *Vikhroli (Accuracy 98.3%)* | *Gandhinagar (Accuracy 100%)* |
|---|---|---|
| *+ 1.38 * numhonks1* | *+ 0.71 * numhonks1* | *+ 1.45 * numhonks1* |
| *+ 0.38 * duration1* | *- 0.21 * duration1* | *+ 0.97 * duration1* |
| *- 0.17 * numhonks2* | *+ 0.15 * numhonks2* | *+ 1.59 * numhonks2* |
| *+ 1.19 * duration2* | *- 0.57 * duration2* | *+ 0.91 * duration2* |
| *- 2.94 * 70speed* | *- 2.71 * 70speed* | *- 0.58 * 70speed* |
| *+ 2.25 * 10speed* | *+ 2.71 * 10speed* | *+ 0.49 * 10speed* |
| *- 1.73* | *- 0.94* | *- 1.98* |

**Attribute weights using binary Sequential Minimal Optimization (SMO) SVM model with linear kernels**

- **Weights assigned to the attributes are in accordance with manual observation**
- **Minimum accuracy obtained in 10 fold cross-validation is 92.7% for Powai (Hiranandani)**

## Unsupervized Learning:

**K-means clustering, with cluster to classes evaluation, gives 65.52% accuracy for Vikhroli. For other roads accuracy is 85-100%**

# Temporal Variation in Traffic

**11:00 am** **4:30 pm** **8:30 pm**

| Time | State | Time | State | Time | State |
|---|---|---|---|---|---|
| 10:30am | F | 11:00am | F | 11:30am | C |
| 12:00noon | C | 12:30pm | F | – | – |
| 4:00pm | F | 4:30pm | F | 5:00pm | F |
| 5:30pm | C | 6:00pm | C | 6:30pm | C |
| 7:00pm | C | 7:30pm | C | 8:00pm | C |
| 8:30pm | C | 9:00pm | C | 9:30pm | C |

**Table 3.4. Traffic State at Bhandup on Dec 1, 2010**

**Seven hours manual ground truth collection on Dec1, 2010**

## Observations

- Six days deployment at Bhandup, Dec1 – Dec3, Dec6 – Dec8, 2010
- Power optimization possible by duty cycling prototype at non-peak hours
- Time series analysis of per minute data necessary to reject outliers
- Time series analysis of per minute data suitable for detecting slow traffic intermediate between free-flowing and congested or vice versa.